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ANTI-TNF ANTIBODIES AND PEPTIDES OF HUMAN TUMOR NECROSIS FACTOR

This application is a continuation of U.S. Application Serial No. 08/192,093, filed February 4, 1994, which is a continuation-in-part of each U.S. Application Serial No. 08/010,406, filed January 29, 1993, now abandoned; and U.S. Application Serial No. 08/013,413, filed February 2, 1993, now abandoned. U.S. Application Serial No. 08/013,413, filed February 2, 1993, is a continuation-in-part of U.S. Application Serial No. 07/943,852, filed September 11, 1992, now abandoned, which is a continuation-in-part of U.S. Application Serial No. 07/853,606, filed March 18, 1992, now abandoned, which is a continuation-in-part of U.S. Application Serial No. 07/670,827, filed March 18, 1991, now abandoned. The above non-abandoned application is entirely incorporated herein by reference.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention in the field of immunology and medicine relates to anti-human tumor necrosis factor-alpha (hTNFα) antibodies and peptides and nucleic acids encoding therefor, and to pharmaceutical and diagnostic compositions and production, diagnostic and therapeutic methods thereof, and to methods for treating TNF-mediated pathologies.

DESCRIPTION OF THE BACKGROUND ART

Tumor Necrosis Factor: Monocytes and macrophages secrete cytokines known as tumor necrosis factor-α (TNFα) and tumor necrosis factor-β (TNFβ) in response to endotoxin or other stimuli. TNFα is a soluble homotrimer of 17 kD protein subunits (Smith, et al., *J. Biol. Chem.* 262:6951-6954 (1987)). A membrane-bound 26 kD precursor form of TNF also exists (Kriegler, et al., *Cell* 53:45-53 (1988)). For reviews of TNF, see Beutler, et al., *Nature* 320:584 (1986), Old, Science 230:630 (1986), and Le, et al., *Lab. Invest.* 56:234 (1987).

Cells other than monocytes or macrophages also make TNFα. For example, human

Spriggs, et al., *Proc. Natl. Acad. Sci. USA* 84:6563 (1987)). $CD4^+$ and $CD8^+$ peripheral blood T lymphocytes and some cultured T and B cell lines (Cuturi, et al., *J. Exp. Med.* 165:1581 (1987); Sung, et al., *J. Exp. Med.* 168:1539 (1988)) also produce TNFα.

TNF causes pro-inflammatory actions which result in tissue injury, such as inducing procoagulant activity on vascular endothelial cells (Pober, et al., *J. Immunol.* 136:1680 (1986)), increasing the adherence of neutrophils and lymphocytes (Pober, et al., *J. Immunol.* 138:3319 (1987)), and stimulating the release of platelet activating factor from macrophages, neutrophils and vascular endothelial cells (Camussi, et al., *J. Exp. Med.* 166:1390 (1987)).

Recent evidence associates TNF with infections (Cerami, et al., *Immunol. Today* 9:28 (1988)), immune disorders, neoplastic pathologies (Oliff, et al., *Cell* 50:555 (1987)), autoimmune pathologies and graft-versus host pathologies (Piguet, et al., *J. Exp. Med.* 166:1280 (1987)). The association of TNF with cancer and infectious pathologies is often related to the host's catabolic state. Cancer patients suffer from weight loss, usually associated with anorexia.

The extensive wasting which is associated with cancer, and other diseases, is known as "cachexia" (Kern, et al. (*J. Parent. Enter. Nutr.* 12:286-298 (1988)). Cachexia includes progressive weight loss, anorexia, and persistent erosion of body mass in response to a malignant growth. The fundamental physiological derangement can relate to a decline in food intake relative to energy expenditure. The cachectic state causes most cancer morbidity and mortality. TNF can mediate cachexia in cancer, infectious pathology, and other catabolic states.

TNF also plays a central role in gram-negative sepsis and endotoxic shock (Michie, et al., *Br. J. Surg.* 76:670-671 (1989); Debets, et al., *Second Vienna Shock Forum*, p.463-466 (1989); Simpson, et al., *Crit. Care Clin.* 5:27-47 (1989)), including fever, malaise, anorexia, and cachexia.

Endotoxin strongly activates monocyte/macrophage production and secretion of TNF and other cytokines (Kornbluth, et al., *J. Immunol.* 137:2585-2591 (1986)). TNF and other monocyte-derived cytokines mediate the metabolic and neurohormonal responses to endotoxin (Michie, et al., *New. Engl. J. Med.* 318:1481-1486 (1988)). Endotoxin administration to human volunteers produces acute illness with flu-like symptoms including fever, tachycardia, increased metabolic rate and stress hormone release (Revhaug, et al., *Arch. Surg.* 123:162-170 (1988)). Circulating TNF increases in patients suffering from Gram-negative sepsis (Waage, et al., *Lancet* 1:355-357 (1987); Hammerle, et al., *Second Vienna Shock Forum* p. 715-718 (1989); Debets, et al., *Crit. Care Med.* 17:489-497 (1989); Calandra, et al., *J. Infect. Dis.* 161:982-987 (1990)).

TNF Antibodies

Polyclonal murine antibodies to TNF are disclosed by Cerami et al. (EPO Patent Publication 0212489, March 4, 1987). Such antibodies were said to be useful in diagnostic immunoassays and in therapy of shock in bacterial infections.

Rubin et al. (EPO Patent Publication 0218868, April 22, 1987) discloses murine monoclonal antibodies to human TNF, the hybridomas secreting such antibodies, methods of producing such murine antibodies, and the use of such murine antibodies in immunoassay of TNF.

Yone et al. (EPO Patent Publication 0288088, October 26, 1988) discloses anti-TNF murine antibodies, including mAbs, and their utility in immunoassay diagnosis of pathologies, in particular Kawasaki's pathology and bacterial infection. The body fluids of patients with Kawasaki's pathology (infantile acute febrile mucocutaneous lymph node syndrome; Kawasaki, *Allergy* 16:178 (1967); Kawasaki, *Shonica (Pediatrics)* 26:935 (1985)) were said to contain elevated TNF levels which were related to progress of the pathology (Yone et al., *infra*).

Other investigators have described rodent or murine mAbs specific for recombinant human TNF which had

neutralizing activity *in vitro* (Liang, et al. (*Biochem. Biophys. Res. Comm.* 137:847-854 (1986); Meager, et al., *Hybridoma* 6:305-311 (1987); Fendly et al., *Hybridoma* 6:359-369 (1987); Bringman, et al., *Hybridoma* 6:489-507 (1987); Hirai, et al., *J. Immunol. Meth.* 96:57-62 (1987); Moller, et al. (*Cytokine* 2:162-169 (1990)). Some of these mAbs were used to map epitopes of human TNF and develop enzyme immunoassays (Fendly et al., *infra*; Hirai et al., *infra*; Moller et al., *infra*) and to assist in the purification of recombinant TNF (Bringman et al., *infra*). However, these studies do not provide a basis for producing TNF neutralizing antibodies that can be used for *in vivo* diagnostic or therapeutic uses in humans, due to immunogenicity, lack of specificity and/or pharmaceutical suitability.

Neutralizing antisera or mAbs to TNF have been shown in mammals other than man to abrogate adverse physiological changes and prevent death after lethal challenge in experimental endotoxemia and bacteremia. This effect has been demonstrated, e.g., in rodent lethality assays and in primate pathology model systems (Mathison, et al., *J. Clin. Invest.* 81:1925-1937 (1988); Beutler, et al., *Science* 229:869-871 (1985); Tracey, et al., *Nature* 330:662-664 (1987); Shimamoto, et al., *Immunol. Lett.* 17:311-318 (1988); Silva, et al., *J. Infect. Dis.* 162:421-427 (1990); Opal, et al., *J. Infect. Dis.* 161:1148-1152 (1990); Hinshaw, et al., *Circ. Shock* 30:279-292 (1990)).

Putative receptor binding loci of hTNF has been disclosed by Eck and Sprang (*J. Biol. Chem.* 264(29), 17595-17605 (1989), who identified the receptor binding loci of TNF-α as consisting of amino acids 11-13, 37-42, 49-57 and 155-157.

PCT publication WO91/02078 (1991) discloses TNF ligands which can bind to monoclonal antibodies having the following epitopes: at least one of 1-20, 56-77, and 108-127; at least two of 1-20, 56-77, 108-127 and 138-149; all of 1-18, 58-65, 115-125 and 138-149; all of 1-18, and 108-128;

all of 56-79, 110-127 and 135- or 136-155; all of 1-30, 117-128 and 141-153; all of 1-26, 117-128 and 141-153; all of 22-40, 49-96 or 49-97, 110-127 and 136-153; all of 12-22, 36-45, 96-105 and 132-157; both of 1-20 and 76-90; all of 22-40, 69-97, 105-128 and 135-155; all of 22-31 and 146-157; all of 22-40 and 49-98; at least one of 22-40, 49-98 and 69-97, both of 22-40 and 70-87.

To date, experience with anti-TNF murine mAb therapy in humans has been limited. In a phase I study, fourteen patients with severe septic shock were administered a murine anti-TNF mAb in a single dose from 0.4-10 mg/kg (Exley, A.R. et al., *Lancet* 335:1275-1277 (1990)). However, seven of the fourteen patients developed a human anti-murine antibody response to the treatment, which treatment suffers from the known problems due to immunogenicity from the use of murine heavy and light chain portions of the antibody. Such immunogenicity causes decreased effectiveness of continued administration and can render treatment ineffective, in patients undergoing diagnostic or therapeutic administration of murine anti-TNF antibodies.

Administration of murine TNF mAb to patients suffering from severe graft versus host pathology has also been reported (Herve, et al., *Lymphoma Res.* 9:591 (1990)).

TNF Receptors

The numerous biological effects of TNFα and the closely related cytokine, TNFβ (lymphotoxin), are mediated by two TNF transmembrane receptors, both of which have been cloned. The p55 receptor (also termed TNF-R55, TNF-RI, or TNFRβ) is a 55 kd glycoprotein shown to transduce signals resulting in cytotoxic, anti-viral, and proliferative activities of TNFα.

The p75 receptor (also termed TNF-R75, TNF-RII, or TNFRα) is a 75 kDa glycoprotein that has also been shown to transduce cytotoxic and proliferative signals as well as signals resulting in the secretion of GM-CSF. The extracellular domains of the two receptors have 28% homology and have in common a set of four subdomains defined by

numerous conserved cysteine residues. The p75 receptor differs, however, by having a region adjacent to the transmembrane domain that is rich in proline residues and contains sites for 0-linked glycosylation. Interestingly, the cytoplasmic domains of the two receptors share no apparent homology which is consistent with observations that they can transduce different signals to the interior of the cell.

TNFα inhibiting proteins have been detected in normal human urine and in serum of patients with cancer or endotoxemia. These have since been shown to be the extracellular domains of TNF receptors derived by proteolytic cleavage of the transmembrane forms. Many of the same stimuli that result in TNFα release also result in the release of the soluble receptors, suggesting that these soluble TNFα inhibitors can serve as part of a negative feedback mechanism to control TNFα activity.

Aderka, et al., *Isrl. J. Med. Sci.* 28:126-130 (1992) discloses soluble forms of TNF receptors (sTNF-Rs) which specifically bind TNF and thus can compete with cell surface TNF receptors to bind TNF (Seckinger, et al., *J. Exp. Med.* 167:1511-1516 (1988); Engelmann, et al., *J. Biol. Chem.* 264:11974-11980 (1989)).

Loetscher, et al., *Cell* 61:351-359 (April 20, 1990) discloses the cloning and expression of human 55 kd TNF receptor with the partial amino acid sequence, complete cDNA sequence and predicted amino acid sequence.

Schall et al., *Cell* 61:361-370 (April 20, 1990), discloses molecular cloning and expression of a receptor for human TNF wherein an isolated cDNA clone including a receptor as a 415 amino acid protein with an apparent molecular weight of 28 kDa, as well as the cDNA sequence and predicted amino acid sequence.

Nophar, et al., *EMBO J.* 9(10):3269-3278 (1990) discloses soluble forms of TNF receptor and that the cDNA for type I TNF-R encodes both the cell surface and soluble forms of the receptor. The cDNA and predicted amino acid sequences

are disclosed.

Engelmann, et al., *J. Biol. Chem.* 265(3):1531-1536 (1990), discloses TNF-binding proteins, purified from human urine, both having an approximate molecular weight of 30 kDa and binding TNF-α more effectively than TNF-β. Sequence data is not disclosed. See also Engelmann, et al., *J. Biol. Chem.* 264(20):11974-11980 (1989).

European Patent publication number 0 433 900 A1, published June 26, 1991, owned by YEDA Research and Developemtn Co., Ltd., Wallach, et al., discloses TNF binding protein I (TBP-I), derivatives and analogs thereof, produced expression of a DNA encoding the entire human type I TNF receptor, or a soluble domain thereof.

PCT publication number WO 92/13095, published August 6, 1992, owned by Synergen, Carmichael et al., discloses methods for treating tumor necrosis factor mediated diseases by administration of a therapeutically effective amount of a TNF inhibitor selected from a 30 kDa TNF inhibitor and a 40 kDa TNF inhibitor selected from the full length 40 kDa TNF inhibitor or modifications thereof.

European Patent Publication number 0 526 905 A2, published October 2, 1993, owned by YEDA Research one Development Company, Ltd., Wallach et al., discloses multimers of the soluble forms of TNF receptors produced by either chemical or recombinant methods which are useful for protecting mammals from the diliterious effects of TNF, which include portions of the hp55 TNF-receptor.

PCT publication WO 92/07076, published April 30, 1992, owned by Charring Cross Sunley Research Center, Feldman et al., discloses modified human TNFα receptor which consists of the first three cysteine-rich subdomain but lacks the fourth Cysteine-rich subdomain of the extracellular binding domain of the 55 kDa or 75 kDa TNF receptor for human TNF α, or an amino acid sequence having a homology of 90% or more with the TNF receptor sequences.

European Patent Publication 0 412 486 A1, published February 13, 1991, owned by YEDA Research and Development

Co., Ltd., Wallach et al., discloses antibodies to TNF binding protein I (TBP-I), and fragments thereof, which can be used as diagnostic assays or pharmaceutical agents, either inhibiting or mimicking the effects of TNF on cells.

European Patent Publication number 0 398 327 A1, published November 22, 1990, owned by YEDA Research and Development Co., Ltd., Wallach et al., discloses TNF binding protein (TBP) isolated and purified having inhibitory activity on the cytotoxic effect of TNF, as well as TNF binding protein II and salts, functional derivatives precursors and active fractions thereof, as well as polyclonal and monoclonal antibodies to TNF binding protein II.

European Patent Publication 0 308 378 A2, published March 22, 1989, owned by YEDA Research and Development Co., Ltd., Wallach, et al., discloses TNF inhibitory protein isolated and substantially purified, having activity to inhibit the binding of TNF to TNF receptors and to inhibit the cytotoxicity of TNF. Additionally disclosed are TNF inhibitory protein, salts, functional derivatives and active fractions thereof, used to antagonize the diliterious effects of TNF.

Accordingly, there is a need to provide novel TNF antibodies or peptides which overcome the problems of murine antibody immunogenicity and which provide reduced immunogenicity and increased neutralization activity.

Citation of documents herein is not intended as an admission that any of the documents cited herein is pertinent prior art, or an admission that the cited documents is considered material to the patentability of any of the claims of the present application. All statements as to the date or representation as to the contents of these documents is based on the information available to the applicant and does not constitute any admission as to the correctness of the dates or contents of these documents.

SUMMARY OF THE INVENTION

It is object of the present invention to overcome one or more deficiencies of the background art.

It is also an object of the present invention to provide methods having utility for *in vitro*, *in situ* and/or *in vivo* diagnosis and/or treatment of animal cells, tissues or pathologies associated with the presence of tumor necrosis factor (TNF), using anti-TNF antibodies and/or anti-TNF peptides.

Anti-TNF antibodies (Abs) are intended to include at least one of monoclonal rodent-human chimeric antibodies, rodent antibodies, human antibodies or any portions thereof, having at least one antigen binding region of an immunoglobulin variable region, which antibody binds TNF.

Anti-TNF peptides are capable of binding TNF under physiological conditions, and can include, but are not limited to, portions of a TNF receptor and/or portions or structural analogs of anti-TNF antibody antigen binding regions or variable regions. Such antibodies or peptides bind TNF with neutralizing and/or inhibiting biological activity.

Anti-TNF antibodies and/or anti-TNF peptides of the present invention can be routinely made and/or used according to methods of the present invention, such as, but not limited to synthetic methods, hybridomas, and/or recombinant cells expressing nucleic acid encoding such anti-TNF antibodies or peptides.

The present invention also provides antigenic polypeptides of hTNF, corresponding to peptides containing neutralizing epitopes or portions of TNF that, when such epitopes on TNF are bound by anti-TNF antibodies or peptides, neutralize or inhibit the biological activity of TNF *in vitro*, *in situ* or *in vivo*.

The present invention also provides anti-TNF antibodies and peptides in the form of pharmaceutical and/or diagnostic compounds and/or compositions, useful for the diagnostic and/or therapeutic methods of the present

invention for diagnosing and/or treating TNF-related pathologies.

Anti-TNF Abs or anti-TNF peptides of the present invention are provided for use in diagnostic methods for detecting TNF in patients or animals suspected of suffering from conditions associated with abnormal TNF production, including methods wherein high affinity anti-TNF antibodies or peptides are contacted with a biological sample from a patient and an antigen-antibody reaction detected. Also included in the present invention are kits for detecting TNF in a solution using anti-TNF antibodies or peptides, preferably in detectably labeled form.

The present invention is also directed to an anti-hTNF chimeric antibody comprising two light chains and two heavy chains, each of the chains comprising at least part of a human constant region and at least part of a variable (V) region of non-human origin having specificity to human TNF, said antibody binding with high affinity to a inhibiting and/or neutralizing epitope of human TNF, such as the antibody cA2. The invention is also includes a fragments or a derivative such an antibody, such as one or more portions of the antibody chain, such as the heavy chain constant, joining, diversity or variable regions, or the light chain constant, joining or variable regions.

Methods are also provided for making and using anti-TNF antibodies and peptides for various utilities of the present invention, such as but not limited to, hybridoma, recombinant or chemical synthetic methods for producing anti-TNF antibodies or anti-TNF peptides according to the present invention; detecting TNF in a solution or cell; removing TNF from a solution or cell, inhibiting one or more biological activities of TNF *in vitro*, *in situ* or *in vitro*. Such removal can include treatment methods of the present invention for alleviating symptoms or pathologies involving TNF, such as, by not limited to bacterial, viral or parasitic infections, chronic inflammatory diseases, autoimmune diseases, malignancies, and/or neurodegenerative diseases.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph showing dose dependent binding of mouse mAb A2 to human TNFα.

Figure 2 is a graph showing lack of recognition of heat-inactivated human TNFα by mAb A2.

Figure 3 is a graph showing neutralization of in vitro TNF cytotoxicity by murine A2. Control: murine IgG1 anti-lipid A mAb (8A1) with natural human TNF. Average absorbance values for controls were as follows: no TNF added = 1.08; natural TNF, no antibody = 0.290; and recombinant TNF, no antibody = 0.500.

Figure 4 is a graph showing that mAb A2 and chimeric A2 do not inhibit or neutralize human lymphotoxin (TNFß). Figure 5 is a graph showing that mAbs murine A2 and chimeric CA2 do not inhibit or neutralize murine TNFα.

Figures 6 and Figure 7 are graphs showing that mAb A2 inhibits or neutralizes TNF produced by chimpanzee monocytes and rhTNFα.

Figure 8 provides schematic diagrams of the plasmids used for expression of the chimeric H (pA2HG1apgpt) and L (pA2HuKapgpt) chains of the chimeric A2 antibody.

Figure 9 is a graph showing results of a cross-blocking epitope ELISA with murine A2 (mA2) and chimeric (cA2) antibody competitors.

Figure 10 is a graph of a Scatchard analysis of ^{125}I-labelled mAb A2 (mA2) and chimeric A2 (cA2) binding to recombinant human TNFα immobilized on a microtiter plate. Each Ka value was calculated from the average of two independent determinations.

Figure 11 is a graph showing neutralization of TNF cytotoxicity by chimeric A2. The control is a chimeric mouse/human IgG1 anti-platelet mAb (7E3) reacting with natural human TNF. Average absorbance values for controls were: no TNF added = 1.08; natural TNF, no Ab = 0.290; and recombinant TNF, no Ab = 0.500.

Figure 12 is a graph showing in vitro neutralization of TNF-induced ELAM-1 expression by chimeric

A2. The control is a chimeric mouse/human IgG1 anti-CD4 antibody.

Figure 13 is an amino acid sequence of human TNF as SEQ ID NO:1.

Figure 14 A-B Figure 14A is a graphical representation of epitope mapping of chimeric mAb cA2 indicating relative binding of cA2 to human TNF peptide pins. Figure 14B is a graphical representation of epitope mapping of chimeric mAb cA2 indicating relative binding of cA2 to human TNF peptide pins in the presence of human TNF.

Figure 15 is an amino acid sequence of human TNF showing sequences having portions of epitopes recognized by cA2, corresponding to portions of amino acids 59-80 and/or 87-108 of SEQ ID NO:1.

Figure 16 A-B Figure 16A is a representation of a space filling model of a human TNF monomer. Figure 16B is a representation of a space filling model of two noncontiguous peptide sequences of human TNF recognized by cA2.

Figure 17 A-B Figure 17A is a nucleic acid sequence (SEQ ID NO:2) and corresponding amino acid sequence (SEQ ID NO:3) of a cloned cA2 variable region. Figure 17B is a nucleic acid sequence (SEQ ID NO:4) and corresponding amino acid sequence (SEQ ID NO:5) of a cloned cA2 constant region (SEQ ID NO:3).

Figure 18 is a graphical representation of the early morning stiffness for the five patients in group I, and the four patients in group II is plotted as the mean percent of the baseline value versus time. Both groups showed an approximately 80 percent decrease or greater in early morning stiffness, which persisted for greater than 40 days.

Figure 19 is a graphical representation of the assessment of pain using a visual analogue scale for the five patients in group I, and the four patients in group II, is plotted as the mean percent of the baseline value versus time. Both groups showed an approximately 60 to 80 percent decrease in pain score which persisted for greater than 40 days.

Figure 20 is a graphical representation of the Ritchie Articular Index, (a scale scored of joint tenderness), is plotted as the mean percent of the baseline value versus time. Both groups showed an approximately 80 percent decrease in the Ritchie Articular Index, which persisted for greater than 40 days.

Figure 21 is a graphical representation of the number of swollen joints for the five patients in group I and the four patients in Group II is plotted as the mean percent of baseline value versus time. Both groups showed an approximately 70 to 80 percent decrease in swollen joints, which persisted for 30 to 40 days.

Figure 22 is a graphical representation of the serum C-reactive protein for four to five patients in group I, and three of the for patients in group II, is plotted as the mean percent of the baseline value versus time. Both groups showed an approximately 80 percent reduction in CRP which persisted for 30 to 40 days. The values for patient number 1 and patient number 7 were omitted from the computations on which the plots are based, since these patients did not have elevated CRP values at baseline.

Figure 23 is a graphical representation of the erythrocyte sedimentation rate for the five patients in group I and three of the patients in group II is plotted as the mean percent of the baseline value versus time. Both groups showed an approximately 40 percent reduction in ESR which persisted for at least 40 days. The data from patient number 9 is omitted from the computations on which the plots were based, since this patient did not have an elevated ESR at baseline.

Figure 24 is a graphical representation of the index of Disease Activity, (a composite score of several parameters of disease activity), for the five patients in group I, and the four patients in group II, is plotted as the mean percent of the baseline value versus time. Both groups showed a clinically significant reduction in IDA, which persisted for at least 40 days.

Figure 25 is a graphical representation of swollen joint counts (maximum 28), as recorded by a single observer. Circles represent individual patients and horizontal bars show median values at each time point. The screening time point was within 4 weeks of entry to the study (week 0); data from patient 15 were not included after week 2 (dropout). Significance of the changes, relative to week 0, by Mann - Whitney test, adjusted: week 1, $p>0.05$; week 2, $p<0.02$; weeks 3-4, $p<0.002$; weeks 6-8, $p<0.001$.

Figure 26 is a graphical representation of levels of serum C - reactive protein (CRP) - Serum CRP (normal range 0-10 mg/liter), measured by nephelometry. Circles represent individual patients and horizontal bars show median values at each time point. The screening time point was within 4 weeks of entry to the study (week 0); data from patient 15 were not included after week 2 (dropout). Significance of the changes, relative to week 0, by Mann-Whitney test, adjusted: week 1, $p<0.001$; week 2, $p<0.003$; week 3, $p<0.002$; week 4, $p<0.02$; week 6,8, $p<0.001$. Figure 27B is a schematic illustration of the construction of the vectors used to express the heavy chain of the immunoreceptors.

Figure 27A-B is aschematic illustration of the genes encoding TNF receptor/IgG fusion proteins and the gene encoding the truncated light chain. The gene encoding Ig heavy chain (IgH) fusion proteins had the same basic structure as the naturally occurring, rearranged Ig genes except that the Ig variable region coding sequence was replaced with TNF receptor coding sequence. Except for the TNF receptor coding sequences and a partial human K sequence derived by modifying the murine J region coding sequence in the cM-T412 IgH gene by PCT mutagenesis, the entire genomic fragment shown originated from the cM-T412 chimeric mouse/human IgH gene. Looney et al., *Hum. Antibody Hybrid.* 3:191-200 (1992). The region deleted in the genes encoding p55-sf3 and p75P-sf3 is marked in the figure. The JC_K gene, encoding a truncated Ig Kappa light chain, was constructed by deleting the variable region coding sequence from the cM-T412

chimeric mouse/human Ig Kappa gene (Looney, *infra*) and using PCR mutagenesis to change the murine J sequence to a partial human J sequence. THe p55-light chain fusion in p55-df2 was made by inserting the p55 coding sequence into the EcoRV site in the JC_K gene. Tracey et al., *Nature* 330:662-666 (1987). Figure 27B is a schematic illustration of several immunoreceptor molecules of the present invention. The blackened ovals each represent a domain of the IgG1 constant region. THe circles represent the truncated light chain. Small circles adjacent to a p55 or p75 subunit mark the positions of human J sequence. The incomplete circles in p75-sf2 and -sf3 are to illustrate that the C-terminal 53 amino acids of the p75 extracellular domain were deleted. Lines between subunits represent disulfide bonds.

Figure 28 is a schematic illustration of the construction of a cM-T412 light chain so that it has a unique cloning site for insertion of foreign genes such as p55 and p75.

Figure 29 is a schematic illustration of the construction of the vectors used to express the light chain of the immunoreceptors.

Figure 30 is a schematic illustration of the construction of a cM-T412 light chain so that it has a unique cloning site for insertion of foreign genes such as p55 and p75.

Figure 31 is a schematic illustration of the construction of the vectors used to express the light chain of the immunoreceptors.

Figure 32 depicts an analysis of purified proteins. Protein A-purified fusion proteins were fractionated by SDS-PAGE through either a 6% non-reducing gel (A) or a 12% reducing gel (B) and stained with Coomassie blue. Lane 1: p55-sf2; lane 2: p55-df2; lane 3: p55-sf3; lane 4: p75-sf2; lane 5: p75P-sf2; lane 6: p75P-sf3; lane 7: cA2, a chimeric mouse/human lgG1 monoclonal antibody. The arrow marks the position of the truncated light chain. Molecular weight markers (in kD) are indicated on the left.

Figure 33A-C shows graphical representations of fusion proteins protected WEHI 164 cells from TNFβ with actinomycin D and then incubated in 2 ng/ml TNFα with varying concentrations of TNFβ overnight at 37°C. Cell viability was determined by measuring their uptake of MTT dye. Figure 33A shows p55 fusion proteins. Figure 33B shows p75 fusion proteins. Figure 33C shows comparison of the protective ability of the non-fusion form of p55 (p55-nf) to p55-sf2.

Figure 34 is a graphical represation of data showing fusion proteins also effectively protect WEHI 164 cells from TNFβ cytotoxicity.

Figure 35A-B is a graphical representation of analyses of binding between the various fusion proteins and TNFα by saturation binding (Figure 35A) and Scatchard analysis (Figure 35B). A microtiter plate was coated with excess goat anti-Fc polyclonal antibody and incubated with 10 ng/ml of fusion protein in TBST buffer (10 mM Tris-HCI, pH 7.8, 150 mM NaCI, 0.05% Tween-20) for 1 hour. Varying amounts of ^{125}I labeled TNFα (specific activity - 34.8 μCi/μg) was then incubated with the captured fusion protein in PBS (10 mM Na Phosphate, pH 7.0, 150 mM NaCl) with 1% bovine serum albumin for 2 hours. Unbound TNFα was washed away with four washes in PBS and the cpm bound was quantitated using a y-counter. All samples were analyzed in triplicate. The slope of the lines in (Figure 35B) represent the affinity constant, K_a. The dissociation constant (K_d) values (see Table I) were derived using the equation $K_d = 1/K_a$.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Tumor necrosis factor (TNF) has been discovered to mediate or be involved in many pathologies, such as, but not limited to bacterial, viral or parasitic infections, chronic inflammatory diseases, autoimmune diseases, malignancies, and/or neurodegenerative diseases. Accordingly, anti-TNF compounds and compositions of the present invention which have neutralizing and/or inhibiting activity against TNF are

discovered to provide methods for treating and/or diagnosing such pathologies.

The present invention thus provides anti-TNF compounds and compositions comprising anti-TNF antibodies (Abs) and/or anti-TNF peptides which inhibit and/or neutralize TNF biological activity *in vitro, in situ and/or in vivo*, as specific for association with neutralizing epitopes of human tumor necrosis factor-alpha (hTNFα) and/or human tumor necrosis factor β (hTNFβ). Such anti-TNF Abs or peptides have utilities for use in research, diagnostic and/or therapeutic methods of the present invention for diagnosing and/or treating animals or humans having pathologies or conditions associated with the presence of a substance reactive with an anti-TNF antibody, such as TNF or metabolic products thereof. Such pathologies can include the generalized or local presence of TNF or related compounds, in amounts and/or concentrations exceeding, or less than, those present in a normal healthy subject, or as related to a pathological condition.

Anti-TNF Antibodies and Methods

The term "antibody" is meant to include polyclonal antibodies, monoclonal antibodies (mAbs), chimeric antibodies, anti-idiotypic (anti-Id) antibodies to antibodies that can be labeled in soluble or bound form, as well as fragments, regions or derivatives thereof, provided by any known technique, such as, but not limited to enzymatic cleavage, peptide synthesis or recombinant techniques. Such anti-TNF antibodies of the present invention are capable of binding portions of TNF that inhibit the binding of TNF to TNF receptors.

Polyclonal antibodies are heterogeneous populations of antibody molecules derived from the sera of animals immunized with an antigen. A monoclonal antibody contains a substantially homogeneous population of antibodies specific to antigens, which population contains substantially similar epitope binding sites. MAbs may be obtained by methods known to those skilled in the art. See, for example Kohler and

Milstein, Nature 256:495-497 (1975); U.S. Patent No. 4,376,110; Ausubel et al, eds., *CURRENT PROTOCOLS IN MOLECULAR BIOLOGY*, Greene Publishing Assoc. and Wiley Interscience, N.Y., (1987, 1992); and Harlow and Lane *ANTIBODIES: A LABORATORY MANUAL* Cold Spring Harbor Laboratory (1988); Colligan et al., eds., *Current Protocols in Immunology*, Greene Publishing Assoc. and Wiley Interscience, N.Y., (1992, 1993), the contents of which references are incoporated entirely herein by reference. Such antibodies may be of any immunoglobulin class including IgG, IgM, IgE, IgA, GILD and any subclass thereof. A hybridoma producing a mAb of the present invention may be cultivated *in vitro*, *in situ* or *in vivo*. Production of high titers of mAbs *in vivo* or *in situ* makes this the presently preferred method of production.

Chimeric antibodies are molecules different portions of which are derived from different animal species, such as those having variable region derived from a murine mAb and a human immunoglobulin constant region, which are primarily used to reduce immunogenicity in application and to increase yields in production, for example, where murine mAbs have higher yields from hybridomas but higher immunogenicity in humans, such that human/murine chimeric mAbs are used. Chimeric antibodies and methods for their production are known in the art (Cabilly et al, *Proc. Natl. Acad. Sci. USA* 81:3273-3277 (1984); Morrison et al., *Proc. Natl. Acad. Sci. USA* 81:6851-6855 (1984); Boulianne et al., *Nature* 312:643-646 (1984); Cabilly et al., European Patent Application 125023 (published November 14, 1984); Neuberger et al., *Nature* 314:268-270 (1985); Taniguchi et al., European Patent Application 171496 (published February 19, 1985); Morrison et al., European Patent Application 173494 (published March 5, 1986); Neuberger et al., PCT Application WO 86/01533, (published March 13, 1986); Kudo et al., European Patent Application 184187 (published June 11, 1986); Morrison et al., European Patent Application 173494 (published March 5, 1986); Sahagan et al., J. Immunol. 137:1066-1074 (1986);

Robinson et al., International Patent Publication #PCT/US86/02269 (published 7 May 1987); Liu et al., Proc. Natl. Acad. Sci. USA 84:3439-3443 (1987); Sun et al., Proc. Natl. Acad. Sci. USA 84:214-218 (1987); Better et al., Science 240:1041- 1043 (1988); and Harlow and Lane ANTIBODIES: A LABORATORY MANUAL Cold Spring Harbor Laboratory (1988)). These references are entirely incorporated herein by reference.

An anti-idiotypic (anti-Id) antibody is an antibody which recognizes unique determinants generally associated with the antigen-binding site of an antibody. An Id antibody can be prepared by immunizing an animal of the same species and genetic type (e.g., mouse strain) as the source of the mAb with the mAb to which an anti-Id is being prepared. The immunized animal will recognize and respond to the idiotypic determinants of the immunizing antibody by producing an antibody to these idiotypic determinants (the anti-Id antibody). See, for example, U.S. patent No. 4,699,880, which is herein entirely incorporated by reference.

The anti-Id antibody may also be used as an "immunogen" to induce an immune response in yet another animal, producing a so-called anti-anti-Id antibody. The anti-anti-Id may be epitopically identical to the original mAb which induced the anti-Id. Thus, by using antibodies to the idiotypic determinants of a mAb, it is possible to identify other clones expressing antibodies of identical specificity.

Anti-TNF antibodies of the present invention can include at least one of a heavy chain constant region (H_c), a heavy chain variable region (H_v), a light chain variable region (L_v) and a light chain constant regions (L_c), wherein a polyclonal Ab, monoclonal Ab, fragment and/or regions thereof include at least one heavy chain variable region (H_v) or light chain variable region (L_v) which binds a portion of a TNF and inhibits and/or neutralizes at least one TNF biological activity.

Preferred antibodies of the present invention are high affinity human-murine chimeric anti-TNF antibodies, and fragments or regions thereof, that have potent inhibiting and/or neutralizing activity *in vivo* against human TNFα. Such antibodies and chimeric antibodies can include those generated by immunization using purified recombinant hTNFα (SEQ ID NO:1) or peptide fragments thereof. Such fragments can include epitopes of at least 5 amino acids of residues 87-107, or a combination of both of 59-80 and 87-108 of hTNFα (as these corresponding amino acids of SEQ ID NO:1). Additionally, preferred antibodies, fragments and regions of anti-TNF antibodies of the present invention do not recognize amino acids from at least one of amino acids 11-13, 37-42, 49-57 or 155-157 of hTNFα (of SEQ ID NO:1).

Preferred anti-TNF mAbs are also those which will competitively inhibit *in vivo* the binding to human TNFα of anti-TNFα murine mAb A2, chimeric mAb cA2, or an antibody having substantially the same specific binding characteristics, as well as fragments and regions thereof. Preferred antibodies of the present invention are those that bind epitopes recognized by A2 and cA2, which are included in amino acids 59-80 and/or 87-108 of hTNFα (as these corresponding amino acids of SEQ ID NO:1), such that the epitopes consist of at least 5 amino acids which comprise at least one amino acid from the above portions of human TNFα.

Preferred methods for determining mAb specificity and affinity by competitive inhibition can be found in Harlow, et al., *Antibodies: A Laboratory Manual*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1988), Colligan et al., eds., *Current Protocols in Immunology*, Greene Publishing Assoc. and Wiley Interscience, N.Y., (1992, 1993), and Muller, *Meth. Enzymol.* 92:589-601 (1983), which references are entirely incorporated herein by reference.

The techniques to raise antibodies of the present invention to small peptide sequences that recognize and bind to those sequences in the free or conjugated form or when presented as a native sequence in the context of a large

protein are well known in the art. Such antibodies include murine, murine human and human-human antibodies produced by hybridoma or recombinant techniques known in the art.

As used herein, the term "antigen binding region" refers to that portion of an antibody molecule which contains the amino acid residues that interact with an antigen and confer on the antibody its specificity and affinity for the antigen. The antibody region includes the "framework" amino acid residues necessary to maintain the proper conformation of the antigen-binding residues.

Preferably, the antigen binding region will be of murine origin. In other embodiments, the antigen binding region can be derived from other animal species, in particular rodents such as rabbit, rat or hamster.

The antigen binding region of the chimeric antibody of the present invention is preferably derived from a non-human antibody specific for human TNF. Preferred sources for the DNA encoding such a non-human antibody include cell lines which produce antibody, preferably hybrid cell lines commonly known as hybridomas. A preferred hybridoma is the A2 hybridoma cell line.

An "antigen" is a molecule or a portion of a molecule capable of being bound by an antibody which is additionally capable of inducing an animal to produce antibody capable of binding to an epitope of that antigen. An antigen can have one or more than one epitope. The specific reaction referred to above is meant to indicate that the antigen will react, in a highly selective manner, with its corresponding antibody and not with the multitude of other antibodies which can be evoked by other antigens. Preferred antigens that bind antibodies, fragments and regions of anti-TNF antibodies of the present invention include at least 5 amino acids comprising at least one of amino acids residues 87-108 or both residues 59-80 and 87-108 of hTNFα (of SEQ ID NO:1). Preferred antigens that bind antibodies, fragments and regions of anti-TNF antibodies of the present invention do not include amino acids of amino

acids 11-13, 37-42, 49-57 or 155-157 of hTNFα (SEQ ID NO:1)

Particular peptides which can be used to generate antibodies of the present invention can include combinations of amino acids selected from at least residues 87-108 or both residues 59-80 and 87-108, which are combined to provide an epitope of TNF that is bound by anti-TNF antibodies, fragments and regions thereof, and which binding provided anti-TNF biological activity. Such epitopes include at least 1-5 amino acids and less than 22 amino acids from residues 87-108 or each of residues 59-80 and 87-108, which in combination with other amino acids of TNF provide epitopes of at least 5 amino acids in length.

TNF residues 87-108 or both residues 59-80 and 87-108 of TNF (of SEQ ID NO:1), fragments or combinations of peptides containing therein are useful as immunogens to raise antibodies that will recognize peptide sequences presented in the context of the native TNF molecule.

The term "epitope" is meant to refer to that portion of any molecule capable of being recognized by and bound by an antibody at one or more of the Ab's antigen binding region. Epitopes usually consist of chemically active surface groupings of molecules such as amino acids or sugar side chains and have specific three dimensional structural characteristics as well as specific charge characteristics. By "inhibiting and/or neutralizing epitope" is intended an epitope, which, when bound by an antibody, results in loss of biological activity of the molecule or organism containing the epitope, *in vivo, in vitro or in situ*, more preferably *in vivo*, including binding of TNF to a TNF receptor.

Epitopes recognized by antibodies, and fragments and regions thereof, of the present invention can include 5 or more amino acids comprising at least one amino acid of each or both of the following amino acid sequences of TNF, which provide a topographical or three dimensional epitope of TNF which is recognized by, and/or binds with anti-TNF activity, an antibody, and fragments, and variable regions

thereof, of the present invention:

59-80: Tyr-Ser-Gln-Val-Leu-Phe-Lys-Gly-Gln-Gly-Cys-Pro-Ser-Thr-His-Val-Leu-Leu-Thr-His-Thr-Ile (AA 59-80 of SEQ ID NO:1); and

87-108: Tyr-Gln-Thr-Lys-Val-Asn-Leu-Leu-Ser-Ala-Ile-Lys-Ser-Pro-Cys-Gln-Arg-Glu-Thr-Pro-Glu-Gly (AA 87-108 of SEQ ID NO:1).

Preferred antibodies, fragments and regions of anti-TNF antibodies of the present invention recognize epitopes including 5 amino acids comprising at least one amino acid from amino acids residues 87-108 or both residues 59-80 and 87-108 of hTNFα (of SEQ ID NO:1). Preferred antibodies, fragments and regions of anti-TNF antibodies of the present invention do not recognize epitopes from at least one of amino acids 11-13, 37-42, 49-57 or 155-157 of hTNFα (of SEQ ID NO:1). In a preferred embodiment, the epitope comprises at least 2 amino acids from residues 87-108 or both residues 59-80 and 87-108 of hTNFα (of SEQ ID NO:1). In another preferred embodiment, the epitope comprises at least 3 amino acids from residues 59-80 and 87-108 of hTNFα (of SEQ ID NO:1). In another preferred embodiment, the epitope comprises at least 4 amino acids from residues 87-108 or both residues 59-80 and 87-108 of hTNFα (of SEQ ID NO:1). In another preferred embodiment, the epitope comprises at least 5 amino acids from residues 87-108 or both residues 59-80 and 87-108 of hTNFα (of SEQ ID NO:1). In another preferred embodiment, the epitope comprises at least 6 amino acids from residues 87-108 or both residues 59-80 and 87-108 of hTNFα (of SEQ ID NO:1). In another preferred embodiment, the epitope comprises at least 7 amino acids from residues 87-108 or both residues 59-80 and 87-108 of hTNFα (of SEQ ID NO:1).

As used herein, the term "chimeric antibody" includes monovalent, divalent or polyvalent immunoglobulins. A monovalent chimeric antibody is a dimer (HL)) formed by a chimeric H chain associated through disulfide bridges with a chimeric L chain. A divalent chimeric antibody is tetramer (H_2L_2) formed by two HL dimers associated through at least one

disulfide bridge. A polyvalent chimeric antibody can also be produced, for example, by employing a C_H region that aggregates (e.g., from an IgM H chain, or μ chain).

Murine and chimeric antibodies, fragments and regions of the present invention comprise individual heavy (H) and/or light (L) immunoglobulin chains. A chimeric H chain comprises an antigen binding region derived from the H chain of a non-human antibody specific for TNF, which is linked to at least a portion of a human H chain C region (C_H), such as CH_1 or CH_2.

A chimeric L chain according to the present invention, comprises an antigen binding region derived from the L chain of a non-human antibody specific for TNF, linked to at least a portion of a human L chain C region (C_L).

Antibodies, fragments or derivatives having chimeric H chains and L chains of the same or different variable region binding specificity, can also be prepared by appropriate association of the individual polypeptide chains, according to known method steps, e.g., according to Ausubel *infra*, Harlow *infra*, and Colligan *infra*, the contents of which references are incoporated entirely herein by reference.

With this approach, hosts expressing chimeric H chains (or their derivatives) are separately cultured from hosts expressing chimeric L chains (or their derivatives), and the immunoglobulin chains are separately recovered and then associated. Alternatively, the hosts can be co-cultured and the chains allowed to associate spontaneously in the culture medium, followed by recovery of the assembled immunoglobulin, fragment or derivative.

The hybrid cells are formed by the fusion of a non-human anti-hTNFα antibody-producing cell, typically a spleen cell of an animal immunized against either natural or recombinant human TNF, or a peptide fragment of the human TNFα protein sequence. Alternatively, the non-human anti-TNFα antibody-producing cell can be a B lymphocyte

obtained from the blood, spleen, lymph nodes or other tissue of an animal immunized with TNF.

The second fusion partner, which provides the immortalizing function, can be lymphoblastoid cell or a plasmacytoma or myeloma cell, which is not itself an antibody producing cell, but is malignant. Preferred fusion partner cells include the hybridoma SP2/0-Ag14, abbreviated as SP2/0 (ATCC CRL1581) and the myeloma P3X63Ag8 (ATCC TIB9), or its derivatives. See, e.g, Ausubel *infra*, Harlow *infra*, and Colligan *infra*, the contents of which references are incoporated entirely herein by reference.

Murine hybridomas which produce mAb specific for human TNFα or TNFβ are formed by the fusion of a mouse fusion partner cell, such as SP2/0, and spleen cells from mice immunized against purified hTNFα, recombinant hTNFα, natural or synthetic TNF peptides, including peptides including 5 or more amino acids selected from residues 59-80, and 87-108 of TNF (of SEQ ID NO:1) or other biological preparations containing TNF. To immunize the mice, a variety of different conventional protocols can be followed. For example, mice can receive primary and boosting immunizations of TNF.

The antibody-producing cell contributing the nucleotide sequences encoding the antigen-binding region of the chimeric antibody of the present invention can also be produced by transformation of a non-human, such as a primate, or a human cell. For example, a B lymphocyte which produces anti-TNF antibody can be infected and transformed with a virus such as Epstein-Barr virus to yield an immortal anti-TNF producing cell (Kozbor et al. *Immunol. Today* 4:72-79 (1983)). Alternatively, the B lymphocyte can be transformed by providing a transforming gene or transforming gene product, as is well-known in the art. See, e.g, Ausubel *infra*, Harlow *infra*, and Colligan *infra*, the contents of which references are incoporated entirely herein by reference.

Antibody Production Using Hybridomas

The cell fusions are accomplished by standard

procedures well known to those skilled in the field of immunology. Fusion partner cell lines and methods for fusing and selecting hybridomas and screening for mAbs are well known in the art. See, e.g, Ausubel *infra*, Harlow *infra*, and Colligan *infra*, the contents of which references are incoporated entirely herein by reference.

The hTNFα-specific murine or chimeric mAb of the present invention can be produced in large quantities by injecting hybridoma or transfectoma cells secreting the antibody into the peritoneal cavity of mice and, after appropriate time, harvesting the ascites fluid which contains a high titer of the mAb, and isolating the mAb therefrom. For such *in vivo* production of the mAb with a non-murine hybridoma (e.g., rat or human), hybridoma cells are preferably grown in irradiated or athymic nude mice. Alternatively, the antibodies can be produced by culturing hybridoma or transfectoma cells *in vitro* and isolating secreted mAb from the cell culture medium or recombinantly, in eukaryotic or prokaryotic cells.

In a preferred embodiment, the antibody is a MAb which binds amino acids of an epitope of TNF, which antibody is designated A2, rA2 or cA2, which is produced by a hybridoma or by a recombinant host. In another preferred embodiment, the antibody is a chimeric antibody which recognizes an epitope recognized by A2. In a more preferred embodiment, the antibody is a chimeric antibody designated as chimeric A2 (cA2).

As examples of antibodies according to the present invention, murine mAb A2 of the present invention is produced by a cell line designated c134A. Chimeric antibody cA2 is produced by a cell line designated c168A. Cell line c134A is deposited as a research cell bank in the Centocor Cell Biology Services Depository, and cell line c168A(RCB) is deposited as a research cell bank in the Centocor Corporate Cell Culture Research and Development Depository, both at Centocor, 200 Great Valley Parkway, Malvern, Pennsylvania, 19355. The c168A cell line is also deposited at Centocor BV,

Leiden, The Netherlands.

Furthermore, c168A was deposited as of the filing date of the present application at the American Type Culture (ATCC No. _____) Collection, Rockville, Maryland, as a "Culture Safe Deposit."

The invention also provides for "derivatives" of the murine or chimeric antibodies, fragments, regions or derivatives thereof, which term includes those proteins encoded by truncated or modified genes to yield molecular species functionally resembling the immunoglobulin fragments. The modifications include, but are not limited to, addition of genetic sequences coding for cytotoxic proteins such as plant and bacterial toxins. The fragments and derivatives can be produced from any of the hosts of this invention. Alternatively, anti-TNF antibodies, fragments and regions can be bound to cytotoxic proteins or compounds *in vitro*, to provide cytotoxic anti-TNF antibodies which would selectively kill cells having TNF receptors.

Fragments include, for example, Fab, Fab', $F(ab')_2$ and Fv. These fragments lack the Fc fragment of intact antibody, clear more rapidly from the circulation, and can have less non-specific tissue binding than an intact antibody (Wahl et al., *J. Nucl. Med.* 24:316-325 (1983)). These fragments are produced from intact antibodies using methods well known in the art, for example by proteolytic cleavage with enzymes such as papain (to produce Fab fragments) or pepsin (to produce $F(ab')_2$ fragments).

The identification of these antigen binding region and/or epitopes recognized by mAbs of the present invention provides the information necessary to generate additional monoclonal antibodies with similar binding characteristics and therapeutic or diagnostic utility that parallel the embodiments of this application.

In a preferred embodiment, the amino acids of the epitope are not of at least one of amino acids 11-13, 37-42, 49-57 and 155-157 of hTNFα (of SEQ ID NO:1).

Unexpectedly, anti-TNF antibodies or peptides of the present invention can block the action of TNF-α without binding to the putative receptor binding locus such as is presented by Eck and Sprang (J. Biol. Chem. 264(29), 17595-17605 (1989), as amino acids 11-13, 37-42, 49-57 and 155-157 of hTNFα (of SEQ ID NO:1).

Recombinant Expression of Anti-TNF Antibodies

Recombinant murine or chimeric murine-human or human-human antibodies that inhibit TNF and bind an epitope included in the amino acid sequences residues 87-108 or both residues 59-80 and 87-108 of hTNFα (of SEQ ID NO:1), can be provided according to the present invention using known techniques based on the teaching provided herein. See, e.g., Ausubel et al., eds. *Current Protocols in Molecular Biology*, Wiley Interscience, N.Y. (1987, 1992, 1993); and Sambrook et al. *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor Laboratory Press (1989), the entire contents of which are incorporated herein by reference.

The DNA encoding an anti-TNF antibody of the present invention can be genomic DNA or cDNA which encodes at least one of the heavy chain constant region (H_c), the heavy chain variable region (H_v), the light chain variable region (L_v) and the light chain constant regions (L_c). A convenient alternative to the use of chromosomal gene fragments as the source of DNA encoding the murine V region antigen-binding segment is the use of cDNA for the construction of chimeric immunoglobulin genes, e.g., as reported by Liu et al. (*Proc. Natl. Acad. Sci., USA* 84:3439 (1987) and *J. Immunology* 139:3521 (1987), which references are hereby entirely incorporated herein by reference. The use of cDNA requires that gene expression elements appropriate for the host cell be combined with the gene in order to achieve synthesis of the desired protein. The use of cDNA sequences is advantageous over genomic sequences (which contain introns), in that cDNA sequences can be expressed in bacteria or other hosts which lack appropriate RNA splicing systems.

For example, a cDNA encoding a murine V region antigen-binding segment having anti-TNF activity can be provided using known methods based on the use of the DNA sequence presented in Figure 17A (SEQ ID NO:2). Alternatively, a cDNA encoding a murine C region antigen-binding segment having anti-TNF activity can be provided using known methods based on the use of the DNA sequence presented in Figure 17B (SEQ ID NO:3). Probes that bind a portion of the DNA sequence presented in Figure 17A or 17B can be used to isolate DNA from hybridomas expressing TNF antibodies, fragments or regions, as presented herein, according to the present invention, by known methods.

Oligonucleotides representing a portion of the variable region presented in Figure 17A or 17B sequence are useful for screening for the presence of homologous genes and for the cloning of such genes encoding variable or constant regions of an anti-TNF antibody. Such probes preferably bind to portions of sequences according to Figures 17A or 17B which encode light chain or heavy chain variable regions which bind an activity inhibiting epitope of TNF, especially an epitope of at least 5 amino acids of residues 87-108 or a combination of residues 59-80 and 87-108 (of SEQ ID NO:1).

Such techniques for synthesizing such oligonucleotides are well known and disclosed by, for example, Wu, et al., *Prog. Nucl. Acid. Res. Molec. Biol.* 21:101-141 (1978)), and Ausubel et al, eds. *Current Protocols in Molecular Biology*, Wiley Interscience (1987, 1993), the entire contents of which are herein incorporated by reference.

Because the genetic code is degenerate, more than one codon can be used to encode a particular amino acid (Watson, et al., *infra*). Using the genetic code, one or more different oligonucleotides can be identified, each of which would be capable of encoding the amino acid. The probability that a particular oligonucleotide will, in fact, constitute the actual XXX-encoding sequence can be estimated by considering abnormal base pairing relationships and the

frequency with which a particular codon is actually used (to encode a particular amino acid) in eukaryotic or prokaryotic cells expressing an anti-TNF antibody or fragment. Such "codon usage rules" are disclosed by Lathe, et al., *J. Molec. Biol.* 183:1-12 (1985). Using the "codon usage rules" of Lathe, a single oligonucleotide, or a set of oligonucleotides, that contains a theoretical "most probable" nucleotide sequence capable of encoding anti-TNF variable or constant region sequences is identified.

Although occasionally an amino acid sequence can be encoded by only a single oligonucleotide, frequently the amino acid sequence can be encoded by any of a set of similar oligonucleotides. Importantly, whereas all of the members of this set contain oligonucleotides which are capable of encoding the peptide fragment and, thus, potentially contain the same oligonucleotide sequence as the gene which encodes the peptide fragment, only one member of the set contains the nucleotide sequence that is identical to the nucleotide sequence of the gene. Because this member is present within the set, and is capable of hybridizing to DNA even in the presence of the other members of the set, it is possible to employ the unfractionated set of oligonucleotides in the same manner in which one would employ a single oligonucleotide to clone the gene that encodes the protein.

The oligonucleotide, or set of oligonucleotides, containing the theoretical "most probable" sequence capable of encoding an anti-TNF antibody or fragment including a variable or constant region is used to identify the sequence of a complementary oligonucleotide or set of oligonucleotides which is capable of hybridizing to the "most probable" sequence, or set of sequences. An oligonucleotide containing such a complementary sequence can be employed as a probe to identify and isolate the variable or constant region anti-TNF gene (Sambrook et al., *infra*).

A suitable oligonucleotide, or set of oligonucleotides, which is capable of encoding a fragment of the variable or constant anti-TNF region (or which is

complementary to such an oligonucleotide, or set of oligonucleotides) is identified (using the above-described procedure), synthesized, and hybridized by means well known in the art, against a DNA or, more preferably, a cDNA preparation derived from cells which are capable of expressing anti-TNF antibodies or variable or constant regions thereof. Single stranded oligonucleotide molecules complementary to the "most probable" variable or constant anti-TNF region peptide coding sequences can be synthesized using procedures which are well known to those of ordinary skill in the art (Belagaje, et al., *J. Biol. Chem.* 254:5765-5780 (1979); Maniatis, et al., *In: Molecular Mechanisms in the Control of Gene Expression*, Nierlich, et al., Eds., Acad. Press, NY (1976); Wu, et al., *Prog. Nucl. Acid Res. Molec. Biol.* 21:101-141 (1978); Khorana, *Science* 203:614-625 (1979)). Additionally, DNA synthesis can be achieved through the use of automated synthesizers. Techniques of nucleic acid hybridization are disclosed by Sambrook et al. (*infra*), and by Haymes, et al. (In: *Nucleic Acid Hybridization, A Practical Approach,* IRL Press, Washington, DC (1985)), which references are herein incorporated by reference. Techniques such as, or similar to, those described above have successfully enabled the cloning of genes for human aldehyde dehydrogenases (Hsu, et al., *Proc. Natl. Acad. Sci. USA* 82:3771-3775 (1985)), fibronectin (Suzuki, et al., *Eur. Mol. Biol. Organ. J.* 4:2519-2524 (1985)), the human estrogen receptor gene (Walter, et al., *Proc. Natl. Acad. Sci. USA* 82:7889-7893 (1985)), tissue-type plasminogen activator (Pennica, et al., *Nature* 301:214-221 (1983)) and human term placental alkaline phosphatase complementary DNA (Kam, et al., *Proc. Natl. Acad. Sci. USA* 82:8715-8719 (1985)).

In an alternative way of cloning a polynucleotide encoding an anti-TNF variable or constant region, a library of expression vectors is prepared by cloning DNA or, more preferably, cDNA (from a cell capable of expressing an anti-TNF antibody or variable or constant region) into an

expression vector. The library is then screened for members capable of expressing a protein which competitively inhibits the binding of an anti-TNF antibody, such as A2 or cA2, and which has a nucleotide sequence that is capable of encoding polypeptides that have the same amino acid sequence as anti-TNF antibodies or fragments thereof. In this embodiment, DNA, or more preferably cDNA, is extracted and purified from a cell which is capable of expressing an anti-TNF antibody or fragment. The purified cDNA is fragmentized (by shearing, endonuclease digestion, etc.) to produce a pool of DNA or cDNA fragments. DNA or cDNA fragments from this pool are then cloned into an expression vector in order to produce a genomic library of expression vectors whose members each contain a unique cloned DNA or cDNA fragment such as in a lambda phage library, expression in prokaryotic cell (e.g., bacteria) or eukaryotic cells, (e.g., mammalian, yeast, insect or fungus). See, e.g., Ausubel, *infra*, Harlow, *infra*, Colligan, *infra*; Nyyssonen et al. *Bio/Technology* 11:591-595 (Can 1993); Marks et al., *Bio/Technology* 11:1145-1149 (October 1993). Once nucleic acid encoding such variable or constant anti-TNF regions is isolated, the nucleic acid can be appropriately expressed in a host cell, along with other constant or variable heavy or light chain encoding nucleic acid, in order to provide recombinant MAbs that bind TNF with inhibitory activity. Such antibodies preferably include a murine or human anti-TNF variable region which contains a framework residue having complimentarily determining residues which are responsible for antigen binding. In a preferred embodiment, an anti-TNF variable light or heavy chain encoded by a nucleic acid as described above binds an epitope of at least 5 amino acids including residues 87-108 or a combination of residues 59-80 and 87-108 of hTNF (of SEQ ID NO:1).

Human genes which encode the constant (C) regions of the murine and chimeric antibodies, fragments and regions of the present invention can be derived from a human fetal liver library, by known methods. Human C regions genes can

be derived from any human cell including those which express and produce human immunoglobulins. The human C_H region can be derived from any of the known classes or isotypes of human H chains, including gamma, μ, α, δ or ϵ, and subtypes thereof, such as G1, G2, G3 and G4. Since the H chain isotype is responsible for the various effector functions of an antibody, the choice of C_H region will be guided by the desired effector functions, such as complement fixation, or activity in antibody-dependent cellular cytotoxicity (ADCC). Preferably, the C_H region is derived from gamma 1 (IgG1), gamma 3 (IgG3), gamma 4 (IgG4), or μ (IgM).

The human C_L region can be derived from either human L chain isotype, kappa or lambda.

Genes encoding human immunoglobulin C regions are obtained from human cells by standard cloning techniques (Sambrook, et al. (*Molecular Cloning: A Laboratory Manual*, 2nd Edition, Cold Spring Harbor Press, Cold Spring Harbor, NY (1989) and Ausubel et al, eds. *Current Protocols in Molecular Biology* (1987-1993)). Human C region genes are readily available from known clones containing genes representing the two classes of L chains, the five classes of H chains and subclasses thereof. Chimeric antibody fragments, such as $F(ab')_2$ and Fab, can be prepared by designing a chimeric H chain gene which is appropriately truncated. For example, a chimeric gene encoding an H chain portion of an $F(ab')_2$ fragment would include DNA sequences encoding the CH_1 domain and hinge region of the H chain, followed by a translational stop codon to yield the truncated molecule.

Generally, the murine, human or murine and chimeric antibodies, fragments and regions of the present invention are produced by cloning DNA segments encoding the H and L chain antigen-binding regions of a TNF-specific antibody, and joining these DNA segments to DNA segments encoding C_H and C_L regions, respectively, to produce murine, human or chimeric immunoglobulin-encoding genes.

Thus, in a preferred embodiment, a fused chimeric

gene is created which comprises a first DNA segment that encodes at least the antigen-binding region of non-human origin, such as a functionally rearranged V region with joining (J) segment, linked to a second DNA segment encoding at least a part of a human C region.

Therefore, cDNA encoding the antibody V and C regions, the method of producing the chimeric antibody according to the present invention involves several steps, outlined below:

1. isolation of messenger RNA (mRNA) from the cell line producing an anti-TNF antibody and from optional additional antibodies supplying heavy and light constant regions; cloning and cDNA production therefrom;
2. preparation of a full length cDNA library from purified mRNA from which the appropriate V and/or C region gene segments of the L and H chain genes can be: (i) identified with appropriate probes, (ii) sequenced, and (iii) made compatible with a C or V gene segment from another antibody for a chimeric antibody;
3. Construction of complete H or L chain coding sequences by linkage of the cloned specific V region gene segments to cloned C region gene, as described above;
4. Expression and production of L and H chains in selected hosts, including prokaryotic and eukaryotic cells to provide murine-murine, human-murine, human-human or human murine antibodies.

One common feature of all immunoglobulin H and L chain genes and their encoded mRNAs is the J region. H and L chain J regions have different sequences, but a high degree of sequence homology exists (greater than 80%) among each group, especially near the C region. This homology is exploited in this method and consensus sequences of H and L chain J regions can be used to design oligonucleotides for

use as primers for introducing useful restriction sites into the J region for subsequent linkage of V region segments to human C region segments.

C region cDNA vectors prepared from human cells can be modified by site-directed mutagenesis to place a restriction site at the analogous position in the human sequence. For example, one can clone the complete human kappa chain C (C_k) region and the complete human gamma-1 C region ($C_{gamma-1}$). In this case, the alternative method based upon genomic C region clones as the source for C region vectors would not allow these genes to be expressed in bacterial systems where enzymes needed to remove intervening sequences are absent. Cloned V region segments are excised and ligated to L or H chain C region vectors. Alternatively, the human $C_{gamma-1}$ region can be modified by introducing a termination codon thereby generating a gene sequence which encodes the H chain portion of an Fab molecule. The coding sequences with linked V and C regions are then transferred into appropriate expression vehicles for expression in appropriate hosts, prokaryotic or eukaryotic.

Two coding DNA sequences are said to be "operably linked" if the linkage results in a continuously translatable sequence without alteration or interruption of the triplet reading frame. A DNA coding sequence is operably linked to a gene expression element if the linkage results in the proper function of that gene expression element to result in expression of the coding sequence.

Expression vehicles include plasmids or other vectors. Preferred among these are vehicles carrying a functionally complete human C_H or C_L chain sequence having appropriate restriction sites engineered so that any V_H or V_L chain sequence with appropriate cohesive ends can be easily inserted therein. Human C_H or C_L chain sequence-containing vehicles thus serve as intermediates for the expression of any desired complete H or L chain in any appropriate host.

A chimeric antibody, such as a mouse-human or

human-human, will typically be synthesized from genes driven by the chromosomal gene promoters native to the mouse H and L chain V regions used in the constructs; splicing usually occurs between the splice donor site in the mouse J region and the splice acceptor site preceding the human C region and also at the splice regions that occur within the human C_H region; polyadenylation and transcription termination occur at native chromosomal sites downstream of the human coding regions.

Non-Limiting Exemplary Chimeric A2 (cA2) Anti-TNF Antibody of the Present Invention

Murine MAbs are undesirable for human therapeutic use, due to a short free circulating serum half-life and the stimulation of a human anti-murine antibody (HAMA) response. A murine-human chimeric anti-human TNFα MAb was developed in the present invention with high affinity, epitope specificity and the ability to neutralize the cytotoxic effects of human TNF. Chimeric A2 anti-TNF consists of the antigen binding variable region of the high-affinity neutralizing mouse anti-human TNF IgG1 antibody, designated A2, and the constant regions of a human IgG1, kappa immunoglobulin. The human IgG1 Fc region is expected to: improve allogeneic antibody effector function; increase the circulating serum half-life; and decrease the immunogenicity of the antibody. A similar murine-human chimeric antibody (chimeric 17-1A) has been shown in clinical studies to have a 6-fold longer in vivo circulation time and to be significantly less immunogenic than its corresponding murine MAb counterpart (LoBuglio et al., *Proc Natl Acad Sci USA* 86: 4220-4224, 1988).

The avidity and epitope specificity of the chimeric A2 is derived from the variable region of the murine A2. In a solid phase ELISA, cross-competition for TNF was observed between chimeric and murine A2, indicating an identical epitope specificity of cA2 and murine A2. The specificity of cA2 for TNF-α was confirmed by its inability to neutralize the cytotoxic effects of lymphotoxin(TNF-β). Chimeric A2 neutralizes the cytotoxic effect of both natural and

recombinant human TNF in a dose dependent manner. From binding assays of cA2 and recombinant human TNF, the affinity constant of cA2 was calculated to be $1.8 \times 10^9 M^{-1}$.

ANTI-TNF Immunoreceptor Peptides

Immunoreceptor peptides of this invention can bind to TNFα and/or TNFβ. The immunoreceptor comprises covalently attached to at least a portion of the TNF receptor at least one immunoglobulin heavy or light chain. In certain preferred embodiments, the heavy chain constant region comprises at least a portion of CH_1. Specifically, where a light chain is included with an immunoreceptor peptide, the heavy chain must include the area of CH_1 responsible for binding a light chain constant region.

An immunoreceptor peptide of the present invention can preferably comprise at least one heavy chain constant region and, in certain embodiments, at least one light chain constant region, with a receptor molecule covalently attached to at least one of the immunoglobulin chains. Light chain or heavy chain variable regions are included in certain embodiments. Since the receptor molecule can be linked within the interior of an immunoglobulin chain, a single chain can have a variable region and a fusion to a receptor molecule.

The portion of the TNF receptor linked to the immunoglobulin molecule is capable of binding TNFα and/or TNFβ. Since the extracellular region of the TNF receptor binds TNF, the portion attached to the immunoglobulin molecule of the immunoreceptor consists of at least a portion of the extracellular region of the TNF receptor. In certain preferred embodiments, the entire extracellular region of p55 is included. In other preferred embodiments, the entire extracellular region of p75 is included. In further preferred embodiments, the extracellular region of p75 is truncated to delete at least a portion of a region of O-linked glycosylation and/or a proline-rich region while leaving intact the intramolecular disulfide bridges. Such

immunoreceptors comprise at least a portion of a hinge region wherein at least one heavy chain is covalently linked to a truncated p75 extracellular region capable of binding to TNFα or TNFβ or both. Such a truncated molecule includes, for example, sequences 1-178, 1-182 or at least 5 amino acid portions thereof, such as 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36,...50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290 or any ?? or value thereon.

Certain embodiments can also include, for example, the C-terminal half of the hinge region to provide a disulfide bridge between heavy chains where both CH_2 and CH_3 chains are present and CH_1 is absent. Alternatively, for example, the N-terminal half of the hinge region can be included to provide a disulfide bridge with a light chain where only the CH_1 region is present.

In certain preferred embodiments of this invention, the non-immunoglobulin molecule is covalently linked to the N-terminus of at least one CH_1 region. In other preferred embodiments, the non-immunoglobulin molecule is covalently linked to an interior section of at least one heavy and/or light chain region. Thus, a portion of the TNF receptor can be, for example, at the end of the immunoglobulin chain or in the middle of the chain.

Where the TNF receptor is attached to the middle of the immunoglobulin, the immunoglobulin chain can be truncated, for example, to compensate for the presence of foreign amino acids, thus resulting in a fusion molecule of approximately the same length as a natural immunoglobulin chain. Alternatively, for example, the immunoglobulin chain can be present substantially in its entirety, thus resulting in a chain that is longer than the corresponding natural immunoglobulin chain. Additionally, the immunoglobulin molecule can be truncated to result in a length intermediate between the size of the entire chain linked to the receptor

molecule and the size of the immunoglobulin chain alone.

In certain preferred embodiments, the heavy chain is an IgG class heavy chain. In other preferred embodiments, the heavy chain is an IgM class heavy chain.

In certain preferred embodiments, the heavy chain further comprises at least about 8 amino acids of a J region.

In certain preferred embodiments, at least a portion of the hinge region is attached to the CH_1 region. For example, where CH_1 and CH_2 are present in the molecule, the entire hinge region is also present to provide the disulfide bridges between the two heavy chain molecules and between the heavy and light chains. Where only CH_1 is present, for example, the molecule need only contain the portion of the hinge region corresponding to the disulfide bridge between the light and heavy chains, such as the first 7 amino acids of the hinge.

It will be understood by one skilled in the art, once armed with the present disclosure, that the immunoreceptor peptides of the invention can be, for example, monomeric or dimeric. For example, the molecules can have only one light chain and one heavy chain or two light chains and two heavy chains.

At least one of the non-immunoglobulin molecules linked to an immunoglobin molecule comprises at least a portion of p55 or at least a portion of p75. The portion of the receptor that is included encompasses the TNF binding site.

In certain preferred embodiments, the non-immunoglobulin molecule comprises at least 5 amino acid segments of sequences 2-159 of p55. In other preferred embodiments, the non-immunoglobulin molecule comprises at least 5 amino acid portions of sequences 1-235 of p75. In further preferred embodiments, the non-immunoglobulin molecule comprises at least 5 amino acid portions of sequences 1-182 of p75. The above 5 amino acid portions can be selected from 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16,

17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36,...50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290.

In certain preferred embodiments, each of the two heavy chains and each of the two light chains is linked to a portion of the TNF receptor, thus forming a tetravalent molecule. Such a tetravalent molecule can have, for example, four p55 receptor molecules; two on the two heavy chains and two on the two light chains. Alternatively, a tetravalent molecule can have, for example, a p55 receptor molecule attached to each of the two heavy chains and a p75 receptor molecule attached to each of the two light chains. A tetravalent molecule can also have, for example, p55 receptor attached to the light chains and p75 receptor attached to the heavy chains. Additionally, a tetravalent molecule can have one heavy chain attached to p55, one heavy chain attached to p75, one light chain attached to p75, and one light chain attached to p55. See, for example, the molecules depicted in Figure 27A. Further, the molecules can have six receptors attached, for example; two within the heavy chains and four at the ends of the heavy and light chains. Other potential multimers and combinations would also be within the scope of one skilled in the art, once armed with the present disclosure.

In further preferred embodiments, at least one of the heavy chains has a variable region capable of binding to a second target molecule. Such molecules include, for example, CD3, so that one half of a fusion molecule is a monomeric anti-CD3 antibody.

Additionally, in other embodiments of the present invention, the immunoreceptor peptides further include an irrelevant variable region on the light chain and/or heavy chain. Preferably, however, such a region is absent due to the lowered affinity for TNF which can be present due to stearic hindrance.

In certain preferred embodiments, the heavy chain

is linked to a non-immunoglobulin molecule capable of binding to a second target molecule, such as a cytotoxic protein, thus creating a part immunoreceptor, part immunotoxin that is capable of killing those cells expressing TNF. Such cytotoxic proteins, include, but are not limited to, Ricin-A, *Pseudomonas* toxin, Diphtheria toxin and TNF. Toxins conjugated to ligands are known in the art (see, for example, Olsnes, S. et al., *Immunol. Today* 1989, 10, 291-295). Plant and bacterial toxins typically kill cells by disruption the protein synthetic machinery.

The Immunoreceptors of this invention can be conjugated to additional types of therapeutic moieties including, but not limited to, radionuclides, cytotoxic agents and drugs. Examples of radionuclides include ^{212}Bi, ^{131}I, ^{186}Re, and ^{90}Y, which list is not intended to be exhaustive. The radionuclides exert their cytotoxic effect by locally irradiating the cells, leading to various intracellular lesions, as is known in the art of radiotherapy.

Cytotoxic drugs which can be conjugated to the immunoreceptors and subsequently used for *in vivo* therapy include, but are not limited to, daunorubicin, doxorubicin, methotrexate, and Mitomycin C. Cytotoxic drugs interfere with critical cellular processes including DNA, RNA, and protein synthesis. For a fuller exposition of these classes of drugs which are known in the art, and their mechanisms of action, see Goodman, A.G., et al., *Goodman and Gilman's The Pharmacological Basis of Therapeutics*, 8th Ed., Macmillan Publishing Col, 1990. Katzung, ed., Basic and Clinical Pharmacology, Fifth Edition, p 768-769, 808-809, 896, Appleton and Lange, Norwalk, Conn.

In preferred embodiments, immunoreceptor molecules of the invention are capable of binding with high affinity to a neutralizing epitope of human TNFα or TNFβ *in vivo*. Preferably, the binding affinity is at least about 1.6 x 10^{10} M-1. See, for example, Table 1 below. Additionally, in

preferred embodiments, immunoreceptor molecules of the invention are capable of neutralizing TNF at an efficiency of about a concentration of less than 130 pM to neutralize 39.2 pM human TNFα. See, for example, Table 1.

Table 1. Summary of affinities of different fusion proteins for TNFα.

protein	IC_{50}*	Molar ration fp: TNFα at IC_{50}	K_D (pM)
p55-sf2	70	1.8	57
p55-df2	55	1.4	60
p55-sf3	100	2.6	48
p55-nf	36,000	900	n.d.
p75-sf2	130	3.3	33
p75P-sf2	70	1.8	29
p75P-sf3	130	3.3	15

*IC_{50} = concentration of fusion protein required to inhibit 2 ng/ml (39.2 pM) TNFα by 50%.62

Once armed with the present disclosure, one skilled in the art would be able to create fragments of the immunoreceptor peptides of the invention. Such fragments are intended to be within the scope off this invention. For example, once the molecules are isolated, they can be cleaved with protease to generate fragments that remain capable of binding TNF.

Once armed with the present disclosure, one skilled in the art would also be able to create derivatives of the immunoreceptor peptides of the invention. Such derivatives are intended to be within the scope of this invention. For example, amino acids in the immunoreceptor that constitute a protease recognition site can be modified to avoid protease cleavage and thus confer greater stability, such as KEX2 sites.

One skilled in the art, once armed with the present

disclosure, would be able to synthesize the molecules of the invention. The immunoreceptor peptides can be constructed, for example, by vector-mediated synthesis, as described in Example XXIV. In general, two expression vectors are preferably used; one for the heavy chain, one for the light chain. A vector for expression an immunoglobulin preferably consists of a promoter linked to the signal sequence, followed by the constant region. The vector additionally preferably contains a gene providing for the selection of transfected cells expressing the construct. In certain preferred embodiments, sequences derived from the J region are also included.

The immunoglobulin gene can be from any vertebrate source, such as murine, but preferably, it encodes an immunoglobulin having a substantial number of sequences that are of the same origin as the eventual recipient of the immunoreceptor peptide. For example, if a human is treated with a molecule of the invention, preferably the immunoglobulin is of human origin.

TNF receptor constructs for linking to the heavy chain can be synthesized, for example, using DNA encoding amino acids present in the cellular domain of the receptor. Putative receptor binding loci of hTNF have been presented by Eck and Sprange, *J. Biol. Chem.* 1989, 264(29), 17595-17605, who identified the receptor binding loci of TNF-α as consisting of amino acids 11-13, 37-42, 49-57 and 155-157. PCT application WO91/02078 (priority date of August 7, 1989) discloses TNF ligands which can bind to monoclonal antibodies having the following epitopes of at least one of 1-20, 56-77, and 108-127; at least two of 1-20, 56-77, 108-127 and 138-149; all of 1-18, 58-65, 115-125 and 138-149; all of 1-18, and 108-128; all of 56-79, 110-127 and 135- or 136-155; all of 1-30, 117-128 and 141-153; all of 1-26, 117-128 and 141-153; all of 22-40, 49-96 or -97, 110-127 and 136-153; all of 12-22, 36-45, 96-105 and 132-157; all of both of 1-20 and 76-90; all of 22-40, 69-97, 105-128 and 135-155; all of 22-31 and 146-157; all of 22-40 and 49-98; at least one of 22-40,

49-98 and 69-97, both of 22-40 and 70-87. Thus, one skilled in the art, once armed with the present disclosure, would be able to create TNF receptor fusion proteins using portions of the receptor that are known to bind TNF.

Advantages of using an immunoglobulin fusion protein (immunoreceptor peptide) of the present invention include one or more of (1) possible increased avidity for multivalent ligands due to the resulting bivalency of dimeric fusion proteins, (2) longer serum half-life, (3) the ability to activate effector cells via the Fc domain, (4) ease of purification (for example, by protein A chromatography), (5) affinity for TNFα and TNFβ and (6) the ability to block TNFα or TNFβ cytotoxicity.

TNF receptor/IgG fusion proteins have shown greater affinity for TNF *α in vitro* than their monovalent, non-fusion counterparts. These types of fusion proteins, which also bind murine TNF with high affinity, have also been shown to protect mice from lipopolysaccharide-induced endotoxemia. Lesslauer et all, *Eur. J. Immunol.* 1991, 21, 2883-2886; and Ashkenazi et al., *Proc. Natl. Acad. Sci. USA* 1991, 88, 10535-10539. Unlike the molecules of the present invention, the TNF receptor/IgG fusion proteins reported to date have had the receptor sequence fused directly to the hinge domain of IgGs such that the first constant domain (CH_1) of the heavy chain was omitted. Lesslauer et al., *Eur. J. Immunol.* 1991, 21, 2883-2886; Ashkenzi et al., *Proc. Natl. Acad. Sci. USA* 1991, 88, 10535-10539; and Peppel et al., *J. Exp. Med.* 1991, 174, 1483-1489.

While this generally permits secretion of the fusion protein in the absence of an Ig light chain, a major embodiment of the present invention provides for the inclusion of the CH_1 domain, which can confer advantages such as (1) increased distance and/or flexibility between two receptor molecules resulting in greater affinity for TNF, (2) the ability to create a heavy chain fusion protein and a light chain fusion protein that would assemble with each

other and dimerize to form a tetravalent (double fusion) receptor molecule, and (3) a tetravalent fusion protein can have increased affinity and/or neutralizing capability for TNF compared to a bivalent (single fusion) molecule.

Unlike other TNF receptor/IgG fusion proteins that have been reported, the fusion proteins of a major embodiment of the present invention include the first constant domain (CH_1) of the heavy chain. The CH_1 domain is largely responsible for interactions with light chains. The light chain, in turn, provides a vehicle for attaching a second set of TNF receptor molecules to the immunoreceptor peptide.

It was discovered using the molecules of the present invention that the p55/light chain fusion proteins and p55/heavy chain fusion proteins would assemble with each other and dimerize to form an antibody-like molecule that is tetravalent with respect to p55. The resulting tetravalent p55 molecules can confer more protection against, and have greater affinity for, TNFα or TNFβ than the bivalent p55 molecules. Despite the presumed close proximity of the two light chain p55 domains to the heavy chain p55 domains, they do not appear to stereocilia hinder or reduce the affinity for TNF.

Inclusion of the CH_1 domain also meant that secretion of the fusion protein was likely to be inefficient in the absence of light chain. This has been shown to be due to a ubiquitous immunoglobulin binding protein (BiP) that binds to the C_H1 domain of heavy chains that are not assembled with a light chain and sequesters them in the endoplasmic reticulum. Karlsson et al., *J. Immunol. Methods* 1991, 145, 229-240.

In initial experiments, an irrelevant light chain was co-transfected with the p55-heavy chain construct and subsequent analyses showed that the two chains did assemble and that the resulting fusion protein protected WEHI cells from TNFα. However, it was considered likely that the variable region of the irrelevant light chain would

stereocilia hinder interactions between the p55 subunits and TNFα. For this reason, a mouse-human chimeric antibody light chain gene was engineered by (1) deleting the variable region coding sequence, and (2) replacing the murine J coding sequence with human J coding sequence. Use of this truncated light chain, which was shown to assemble and disulfide bond with heavy chains, increased the efficiency of TNF inhibition by approximately 30-fold compared to use of a complete irrelevant light chain.

Comparison of the abilities of p75-sf2 and p75P-sf2 to inhibit TNF cytotoxicity indicated that the C-terminal 53 amino acids of the extracellular domain of p75, which defines a region that is rich in proline residues and contains the only sites of O-linked glycosylation, are not necessary for high-affinity binding to TNFα or TNFβ. In fact, the p75P-sf2 construct repeatedly showed higher affinity binding to TNFβ than p75-sf2. Surprisingly, there was no difference observed between the two constructs in their affinity for TNFα.

It is possible that a cell-surface version of p75-P would also bind TNFβ with higher affinity than the complete p75 extracellular domain. A similar region is found adjacent to the transmembrane domain in the low affinity nerve growth factor receptor whose extracellular domain shows the same degree of similarity to p75 as p55 does. Mallett et al., *Immunol. Today* 1991, 12, 220-223.

Two groups have reported that in cell cytotoxicity assays, their p55 fusion protein could be present at a 3-fold (Lesslauer et al., *Eur. J. Immunol.* 1991, 21, 2883-2886) or 6-8 fold (Ashkenazi et al., *Proc. Natl. Acad. Sci. USA* 1991, 88, 10535-10539) lower concentration than their monovalent p55 and still get the same degree of protection, while another group (Peppel et al., *J. Exp. Med.* 1991, 174, 1483-1489) showed that their p55 fusion protein could be present at a 1000-fold lower concentration than monomeric p55. Thus, the prior art has shown unpredictability in the great variability in the efficiency of different fusion proteins.

The molecules of the present invention have

demonstrated the same degree of protection against TNF in a 5000-fold lower molar concentration than monomeric p55. (See Table 1.) It is believed that the presence of the CH_1 chain in the molecules of a major embodiment of the present invention can confer greater flexibility to the molecule and avoid stearic hindrance with the binding of the TNF receptor.

Recombinant Expression of Anti-TNF Antibodies and Anti-TNF Peptides.

A nucleic acid sequence encoding at least one anti-TNF peptide or Ab fragment of the present invention may be recombined with vector DNA in accordance with conventional techniques, including blunt-ended or staggered-ended termini for ligation, restriction enzyme digestion to provide appropriate termini, filling in of cohesive ends as appropriate, alkaline phosphatase treatment to avoid undesirable joining, and ligation with appropriate ligases. Techniques for such manipulations are disclosed, e.g., by Ausubel, *infra*, Sambrook, *infra*, entirely incorporated herein by reference, and are well known in the art.

A nucleic acid molecule, such as DNA, is said to be "capable of expressing" a polypeptide if it contains nucleotide sequences which contain transcriptional and translational regulatory information and such sequences are "operably linked" to nucleotide sequences which encode the polypeptide. An operable linkage is a linkage in which the regulatory DNA sequences and the DNA sequence sought to be expressed are connected in such a way as to permit gene expression as anti-TNF peptides or Ab fragments in recoverable amounts. The precise nature of the regulatory regions needed for gene expression may vary from organism to organism, as is well known in the analogous art. See, e.g., Sambrook, *supra* and Ausubel *supra*.

The present invention accordingly encompasses the expression of an anti-TNF peptide or Ab fragment, in either prokaryotic or eukaryotic cells, although eukaryotic expression is preferred.

Preferred hosts are bacterial or eukaryotic hosts including bacteria, yeast, insects, fungi, bird and mammalian cells either *in vivo*, or *in situ*, or host cells of mammalian, insect, bird or yeast origin. It is preferred that the mammalian cell or tissue is of human, primate, hamster, rabbit, rodent, cow, pig, sheep, horse, goat, dog or cat origin, but any other mammalian cell may be used.

Further, by use of, for example, the yeast ubiquitin hydrolase system, *in vivo* synthesis of ubiquitin-transmembrane polypeptide fusion proteins may be accomplished. The fusion proteins so produced may be processed *in vivo* or purified and processed *in vitro*, allowing synthesis of an anti-TNF peptide or Ab fragment of the present invention with a specified amino terminus sequence. Moreover, problems associated with retention of initiation codon-derived methionine residues in direct yeast (or bacterial) expression may be avoided. Sabin et al., *Bio/Technol.* 7(7): 705-709 (1989); Miller et al., *Bio/Technol.* 7(7): 698-704 (1989).

Any of a series of yeast gene expression systems incorporating promoter and termination elements from the actively expressed genes coding for glycolytic enzymes produced in large quantities when yeast are grown in mediums rich in glucose can be utilized to obtain anti-TNF peptides or Ab fragments of the present invention. Known glycolytic genes can also provide very efficient transcriptional control signals. For example, the promoter and terminator signals of the phosphoglycerate kinase gene can be utilized.

Production of anti-TNF peptides or Ab fragments or functional derivatives thereof in insects can be achieved, for example, by infecting the insect host with a baculovirus engineered to express transmembrane polypeptide by methods known to those of skill. See Ausubel et al, eds. *Current Protocols in Molecular Biology*, Wiley Interscience, §§16.8-16.11 (1987, 1993).

In a preferred embodiment, the introduced nucleotide sequence will be incorporated into a plasmid or

viral vector capable of autonomous replication in the recipient host. Any of a wide variety of vectors may be employed for this purpose. See, e.g., Ausubel et al, *infra*, §§ 1.5, 1.10, 7.1, 7.3, 8.1, 9.6, 9.7, 13.4, 16.2, 16.6, and 16.8-16.11. Factors of importance in selecting a particular plasmid or viral vector include: the ease with which recipient cells that contain the vector may be recognized and selected from those recipient cells which do not contain the vector; the number of copies of the vector which are desired in a particular host; and whether it is desirable to be able to "shuttle" the vector between host cells of different species.

Preferred prokaryotic vectors known in the art include plasmids such as those capable of replication in E. coli (such as, for example, pBR322, ColE1, pSC101, pACYC 184, πVX). Such plasmids are, for example, disclosed by Maniatis, T., et al. (*Molecular Cloning, A Laboratory Manual*, Second Edition, Cold Spring Harbor Press, Cold Spring Harbor, NY (1989); Ausubel, *infra*. Bacillus plasmids include pC194, pC221, pT127, etc. Such plasmids are disclosed by Gryczan, T. (In: *The Molecular Biology of the Bacilli*, Academic Press, NY (1982), pp. 307-329). Suitable Streptomyces plasmids include pIJ101 (Kendall, K.J., et al., *J. Bacteriol.* 169:4177-4183 (1987)), and streptomyces bacteriophages such as φC31 (Chater, K.F., et al., In: *Sixth International Symposium on Actinomycetales Biology*, Akademiai Kaido, Budapest, Hungary (1986), pp. 45-54). Pseudomonas plasmids are reviewed by John, J.F., et al. (*Rev. Infect. Dis.* 8:693-704 (1986)), and Izaki, K. (*Jpn. J. Bacteriol.* 33:729-742 (1978); and Ausubel et al, supra).

Alternatively, gene expression elements useful for the expression of cDNA encoding anti-TNF antibodies or peptides include, but are not limited to (a) viral transcription promoters and their enhancer elements, such as the SV40 early promoter (Okayama, et al., *Mol. Cell. Biol.* 3:280 (1983)), Rous sarcoma virus LTR (Gorman, et al., *Proc. Natl. Acad. Sci., USA* 79:6777 (1982)), and Moloney murine

leukemia virus LTR (Grosschedl, et al., *Cell* 41:885 (1985)); (b) splice regions and polyadenylation sites such as those derived from the SV40 late region (Okayama et al., *infra*); and (c) polyadenylation sites such as in SV40 (Okayama et al., *infra*).

Immunoglobulin cDNA genes can be expressed as described by Liu et al., *infra*, and Weidle et al., *Gene* 51:21 (1987), using as expression elements the SV40 early promoter and its enhancer, the mouse immunoglobulin H chain promoter enhancers, SV40 late region mRNA splicing, rabbit ß-globin intervening sequence, immunoglobulin and rabbit ß-globin polyadenylation sites, and SV40 polyadenylation elements. For immunoglobulin genes comprised of part cDNA, part genomic DNA (Whittle et al., *Protein Engineering* 1:499 (1987)), the transcriptional promoter is human cytomegalovirus, the promoter enhancers are cytomegalovirus and mouse/human immunoglobulin, and mRNA splicing and polyadenylation regions are from the native chromosomal immunoglobulin sequences.

In one embodiment, for expression of cDNA genes in rodent cells, the transcriptional promoter is a viral LTR sequence, the transcriptional promoter enhancers are either or both the mouse immunoglobulin heavy chain enhancer and the viral LTR enhancer, the splice region contains an intron of greater than 31 bp, and the polyadenylation and transcription termination regions are derived from the native chromosomal sequence corresponding to the immunoglobulin chain being synthesized. In other embodiments, cDNA sequences encoding other proteins are combined with the above-recited expression elements to achieve expression of the proteins in mammalian cells.

Each fused gene is assembled in, or inserted into, an expression vector. Recipient cells capable of expressing the chimeric immunoglobulin chain gene product are then transfected singly with an anti-TNF peptide or chimeric H or chimeric L chain-encoding gene, or are co-transfected with a chimeric H and a chimeric L chain gene. The transfected recipient cells are cultured under conditions that permit

expression of the incorporated genes and the expressed immunoglobulin chains or intact antibodies or fragments are recovered from the culture.

In one embodiment, the fused genes encoding the anti-TNF peptide or chimeric H and L chains, or portions thereof, are assembled in separate expression vectors that are then used to co-transfect a recipient cell.

Each vector can contain two selectable genes, a first selectable gene designed for selection in a bacterial system and a second selectable gene designed for selection in a eukaryotic system, wherein each vector has a different pair of genes. This strategy results in vectors which first direct the production, and permit amplification, of the fused genes in a bacterial system. The genes so produced and amplified in a bacterial host are subsequently used to co-transfect a eukaryotic cell, and allow selection of a co-transfected cell carrying the desired transfected genes.

Examples of selectable genes for use in a bacterial system are the gene that confers resistance to ampicillin and the gene that confers resistance to chloramphenicol. Preferred selectable genes for use in eukaryotic transfectants include the xanthine guanine phosphoribosyl transferase gene (designated *gpt*) and the phosphotransferase gene from Tn5 (designated *neo*).

Selection of cells expressing *gpt* is based on the fact that the enzyme encoded by this gene utilizes xanthine as a substrate for purine nucleotide synthesis, whereas the analogous endogenous enzyme cannot. In a medium containing (1) mycophenolic acid, which blocks the conversion of inosine monophosphate to xanthine monophosphate, and (2) xanthine, only cells expressing the gpt gene can survive. The product of the neo blocks the inhibition of protein synthesis by the antibiotic G418 and other antibiotics of the neomycin class.

The two selection procedures can be used simultaneously or sequentially to select for the expression of immunoglobulin chain genes introduced on two different DNA vectors into a eukaryotic cell. It is not necessary to

include different selectable markers for eukaryotic cells; an H and an L chain vector, each containing the same selectable marker can be co-transfected. After selection of the appropriately resistant cells, the majority of the clones will contain integrated copies of both H and L chain vectors and/or anti-TNF peptides.

Alternatively, the fused genes encoding the chimeric H and L chains can be assembled on the same expression vector.

For transfection of the expression vectors and production of the chimeric antibody, the preferred recipient cell line is a myeloma cell. Myeloma cells can synthesize, assemble and secrete immunoglobulins encoded by transfected immunoglobulin genes and possess the mechanism for glycosylation of the immunoglobulin. A particularly preferred recipient cell is the recombinant Ig-producing myeloma cell SP2/0 (ATCC #CRL 8287). SP2/0 cells produce only immunoglobulin encoded by the transfected genes. Myeloma cells can be grown in culture or in the peritoneal cavity of a mouse, where secreted immunoglobulin can be obtained from ascites fluid. Other suitable recipient cells include lymphoid cells such as B lymphocytes of human or non-human origin, hybridoma cells of human or non-human origin, or interspecies heterohybridoma cells.

The expression vector carrying a chimeric antibody construct or anti-TNF peptide of the present invention can be introduced into an appropriate host cell by any of a variety of suitable means, including such biochemical means as transformation, transfection, conjugation, protoplast fusion, calcium phosphate-precipitation, and application with polycations such as diethylaminoethyl (DEAE) dextran, and such mechanical means as electroporation, direct microinjection, and microprojectile bombardment (Johnston et al., *Science* 240:1538 (1988)). A preferred way of introducing DNA into lymphoid cells is by electroporation (Potter et al., *Proc. Natl. Acad. Sci. USA* 81:7161 (1984); Yoshikawa, et al., *Jpn. J. Cancer Res.* 77:1122-1133). In

this procedure, recipient cells are subjected to an electric pulse in the presence of the DNA to be incorporated. Typically, after transfection, cells are allowed to recover in complete medium for about 24 hours, and are then seeded in 96-well culture plates in the presence of the selective medium. G418 selection is performed using about 0.4 to 0.8 mg/ml G418. Mycophenolic acid selection utilizes about 6μg/ml plus about 0.25 mg/ml xanthine. The electroporation technique is expected to yield transfection frequencies of about 10^{-5} to about 10^{-4} for Sp2/0 cells. In the protoplast fusion method, lysozyme is used to strip cell walls from catarrhal harboring the recombinant plasmid containing the chimeric antibody gene. The resulting spheroplasts are fused with myeloma cells with polyethylene glycol.

The immunoglobulin genes of the present invention can also be expressed in nonlymphoid mammalian cells or in other eukaryotic cells, such as yeast, or in prokaryotic cells, in particular bacteria.

Yeast provides substantial advantages over bacteria for the production of immunoglobulin H and L chains. Yeasts carry out post-translational peptide modifications including glycosylation. A number of recombinant DNA strategies now exist which utilize strong promoter sequences and high copy number plasmids which can be used for production of the desired proteins in yeast. Yeast recognizes leader sequences of cloned mammalian gene products and secretes peptides bearing leader sequences (i.e., pre-peptides) (Hitzman, et al., *11th International Conference on Yeast, Genetics and Molecular Biology*, Montpelier, France, September 13-17, 1982).

Yeast gene expression systems can be routinely evaluated for the levels of production, secretion and the stability of anti-TNF peptides, antibody and assembled murine and chimeric antibodies, fragments and regions thereof. Any of a series of yeast gene expression systems incorporating promoter and termination elements from the actively expressed genes coding for glycolytic enzymes produced in large

quantities when yeasts are grown in media rich in glucose can be utilized. Known glycolytic genes can also provide very efficient transcription control signals. For example, the promoter and terminator signals of the phosphoglycerate kinase (PGK) gene can be utilized. A number of approaches can be taken for evaluating optimal expression plasmids for the expression of cloned immunoglobulin cDNAs in yeast (see Glover, ed., *DNA Cloning, Vol. II*, pp45-66, IRL Press, 1985).

Bacterial strains can also be utilized as hosts for the production of antibody molecules or peptides described by this invention, *E. coli* K12 strains such as *E. coli* W3110 (ATCC 27325), and other enterobacteria such as *Salmonella typhimurium or Serratia marcescens*, and various *Pseudomonas* species can be used.

Plasmid vectors containing replicon and control sequences which are derived from species compatible with a host cell are used in connection with these bacterial hosts. The vector carries a replication site, as well as specific genes which are capable of providing phenotypic selection in transformed cells. A number of approaches can be taken for evaluating the expression plasmids for the production of murine and chimeric antibodies, fragments and regions or antibody chains encoded by the cloned immunoglobulin cDNAs in bacteria (see Glover, ed., *DNA Cloning, Vol. I*, IRL Press, 1985, Ausubel, *infra*, Sambrook, *infra*, Colligan, *infra*).

Preferred hosts are mammalian cells, grown *in vitro* or *in vivo*. Mammalian cells provide post-translational modifications to immunoglobulin protein molecules including leader peptide removal, folding and assembly of H and L chains, glycosylation of the antibody molecules, and secretion of functional antibody protein.

Mammalian cells which can be useful as hosts for the production of antibody proteins, in addition to the cells of lymphoid origin described above, include cells of fibroblast origin, such as Vero (ATCC CRL 81) or CHO-K1 (ATCC CRL 61).

Many vector systems are available for the

expression of cloned anti TNF peptides H and L chain genes in mammalian cells (see Glover, ed., *DNA Cloning, Vol. II*, pp143-238, IRL Press, 1985). Different approaches can be followed to obtain complete H_2L_2 antibodies. As discussed above, it is possible to co-express H and L chains in the same cells to achieve intracellular association and linkage of H and L chains into complete tetrameric H_2L_2 antibodies and/or anti-TNF peptides. The co-expression can occur by using either the same or different plasmids in the same host. Genes for both H and L chains and/or anti-TNF peptides can be placed into the same plasmid, which is then transfected into cells, thereby selecting directly for cells that express both chains. Alternatively, cells can be transfected first with a plasmid encoding one chain, for example the L chain, followed by transfection of the resulting cell line with an H chain plasmid containing a second selectable marker. Cell lines producing anti-TNF peptides and/or H_2L_2 molecules via either route could be transfected with plasmids encoding additional copies of peptides, H, L, or H plus L chains in conjunction with additional selectable markers to generate cell lines with enhanced properties, such as higher production of assembled H_2L_2 antibody molecules or enhanced stability of the transfected cell lines.

Anti-idiotype Abs. In addition to monoclonal or chimeric anti-TNF antibodies, the present invention is also directed to an anti-idiotypic (anti-Id) antibody specific for the anti-TNF antibody of the invention. An anti-Id antibody is an antibody which recognizes unique determinants generally associated with the antigen-binding region of another antibody. The antibody specific for TNF is termed the idiotypic or Id antibody. The anti-Id can be prepared by immunizing an animal of the same species and genetic type (e.g. mouse strain) as the source of the Id antibody with the Id antibody or the antigen-binding region thereof. The immunized animal will recognize and respond to the idiotypic determinants of the immunizing antibody and produce an

anti-Id antibody. The anti-Id antibody can also be used as an "immunogen" to induce an immune response in yet another animal, producing a so-called anti-anti-Id antibody. The anti-anti-Id can be epitopically identical to the original antibody which induced the anti-Id. Thus, by using antibodies to the idiotypic determinants of a mAb, it is possible to identify other clones expressing antibodies of identical specificity.

Accordingly, mAbs generated against TNF according to the present invention can be used to induce anti-Id antibodies in suitable animals, such as BALB/c mice. Spleen cells from such immunized mice can be used to produce anti-Id hybridomas secreting anti-Id mAbs. Further, the anti-Id mAbs can be coupled to a carrier such as keyhole limpet hemocyanin (KLH) and used to immunize additional BALB/c mice. Sera from these mice will contain anti-anti-Id antibodies that have the binding properties of the original mAb specific for a TNF epitope.

Screening Methods for determining tissue necrosis factor neutralizing and/or inhibiting activity are also provided in the present invention. In the context of the present invention, TNF neutralizing activity or TNF inhibiting activity refers to the ability of a TNF neutralizing compound to block at least one biological activity of TNF, such as preventing TNF from binding to a TNF receptor, blocking production of TNF by intracellular processing, such as transcription, translation or post-translational modification, expression on the cell surface, secretion or assembly of the bioactive trimer of TNF. Additionally, TNF neutralizing compounds can act by inducing regulation of metabolic pathways such as those involving the up or down regulation of TNF production. Alternatively TNF neutralizing compounds can modulate cellular sensitivity to TNF by decreasing such sensitivity. TNF neutralizing compounds can be ?? from the group consisting of antibodies, or fragments or portions thereof, peptides, peptido mimetic compounds or organo mimetic compounds that neutralizes TNF

activity in vitro, in situ or in vivo is considered a TNF neutralizing compound if used according to the present invention. Screening methods which can be used to determine TNF neutralizing activity of a TNF neutralizing compound can include in vitro or in vivo assays. Such in vitro assays can include a TNF cytotoxicity assay, such as a radioimmuno assay which determine a decrease in cell death by contact with TNF, such as chimpanzee or human TNF in isolated or recombinant form, wherein the concurrent presence of a TNF neutralizing compound reduces the degree or rate of cell death. The cell death can be determined using ID50 values which represent the concentration of a TNF neutralizing compound which decreases the cell death rate by 50%. For example, MAb's A2 and cA2 are found to have ID50 about 17mg/ml +/- 3mg/ml, such as 14-20mg/ml, or any range or value therein. Such a TNF cytotoxicity assay is presented in example II.

Alternatively or additionally, another *in vitro* assay which can be used to determine neutralizing activity of a TNF neutralizing compound is an assay which measures the neutralization of TNF induced procoagulant activity, such as presented in example XI.

Alternatively or additionally, TNF neutralizing activity of a TNF neutralizing compound can be measured by an assay for the neutralization of TNF induced IL-6 secretion, such as using cultured human umbilical vein endothelial cells (HUVEC), for example. Also presented in example 11.

Alternatively or additionally, in vivo testing of TNF neutralizing activity of TNF neutralizing compounds can be tested using survival of mouse given lethal doses of Rh TNF with controlled and varied concentrations of a TNF neutralizing compound, such as TNF antibodies. Preferably galactosamine sensitive mice are used. For example, using a chimeric human anti-TNF antibody as a TNF neutralizing compound, a concentration of 0.4 milligrams per kilogram TNF antibody resulted in a 70-100% increase in survival and a 2.0mg/kg dose of TNF antibody resulted in a 90-100% increase in survival rate using such an assay, for example, as

presented in example 12.

Additionally, after TNF neutralizing compounds are tested for safety in animal models such as chimpanzees, for example as presented in Example XVII, TNF neutralizing compounds can be used to treat various TNF related pathologies, as described herein, and as presented in Examples XVIII-XXII.

Accordingly, any suitable TNF neutralizing compound can be used in methods according to the present invention. Examples of such TNF neutralizing compound can be selected from the group consisting of antibodies or portions thereof specific to neutralizing epitopes of TNF, p55 receptors, p75 receptors, or complexes thereof, portions of TNF receptors which bind TNF, peptides which bind TNF, any peptido mimetic drugs which bind TNF and any organo mimetic drugs that block TNF.

Such TNF neutralizing compounds can be determined by routine experimentation based on the teachings and guidance presented herein, by those skilled in the relevant arts.

Structural Analogs of Anti-TNF Antibodies and Anti-TNF Peptides

Structural analogs of anti-TNF Abs and peptides of the present invention are provided by known method steps based on the teaching and guidance presented herein.

Knowledge of the three-dimensional structures of proteins is crucial in understanding how they function. The three-dimensional structures of more than 400 proteins are currently available in protein structure databases (in contrast to around 15,000 known protein sequences in sequence databases). Analysis of these structures shows that they fall into recognizable classes of motifs. It is thus possible to model a three-dimensional structure of a protein based on the proteins homology to a related protein of known structure. Many examples are known where two proteins that have relatively low sequence homology, can have very similar three dimensional structures or motifs.

In recent years it has become possible to determine the three dimensional structures of proteins of up to about 15 kDa by nuclear magnetic resonance (NMR). The technique only requires a concentrated solution of pure protein. No crystals or isomorphous derivatives are needed. The structures of a number proteins have been determined by this method. The details of NMR structure determination are well-known in the art (See, e.g., Wuthrich, *NMR of Proteins and Nucleic Acids*, Wiley, New York, 1986; Wuthrich, K. *Science* 243:45-50 (1989); Clore et al., *Crit. Rev. Bioch. Molec. Biol.* 24:479-564 (1989); Cooke et al. *Bioassays* 8:52-56 (1988), which references are hereby incorporated herein by reference).

In applying this approach, a variety of ^{1}H NMR 2D data sets are collected for anti-TNF Abs and/or anti-TNF peptides of the present invention. These are of two main types. One type, COSY (Correlated Spectroscopy) identifies proton resonances that are linked by chemical bonds. These spectra provide information on protons that are linked by three or less covalent bonds. NOESY (nuclear Overhauser enhancement spectroscopy) identifies protons which are close in space (less than 0.5 nm). Following assignment of the complete spin system, the secondary structure is defined by NOESY. Cross peaks (nuclear Overhauser effects or NOE's) are found between residues that are adjacent in the primary sequence of the peptide and can be seen for protons less than 0.5nm apart. The data gathered from sequential NOE's combined with amide proton coupling constants and NOE's from non-adjacent amino acids, that are adjacent to the secondary structure, are used to characterize the secondary structure of the polypeptides. Aside from predicting secondary structure, NOE's indicate the distance that protons are in space in both the primary amino acid sequence and the secondary structures. Tertiary structure predictions are determined, after all the data are considered, by a "best fit" extrapolation.

Types of amino acid are first identified using

through-bond connectivities. The second step is to assign specific amino acids using through-space connectivities to neighboring residues, together with the known amino acid sequence. Structural information is then tabulated and is of three main kinds: The NOE identifies pairs of protons which are close in space, coupling constants give information on dihedral angles and slowly exchanging amide protons give information on the position of hydrogen bonds. The restraints are used to compute the structure using a distance geometry type of calculation followed by refinement using restrained molecular dynamics. The output of these computer programs is a family of structures which are compatible with the experimental data (i.e. the set of pairwise <0.5nm distance restraints). The better that the structure is defined by the data, the better the family of structures can be superimposed, (i.e., the better the resolution of the structure). In the better defined structures using NMR, the position of much of backbone (i.e. the amide, Cα and carbonyl atoms) and the side chains of those amino acids that lie buried in the core of the molecule can be defined as clearly as in structures obtained by crystallography. The side chains of amino acid residues exposed on the surface are frequently less well defined, however. This probably reflects the fact that these surface residues are more mobile and can have no fixed position. (In a crystal structure this might be seen as diffuse electron density).

Thus, according to the present invention, use of NMR spectroscopic data is combined with computer modeling to arrive structural analogs of at least portions of anti-TNF Abs and peptides based on a structural understanding of the topography. Using this information, one of ordinary skill in the art will know how to achieve structural analogs of anti-TNF Abs and/or peptides, such as by rationally-based amino acid substitutions allowing the production of peptides in which the TNF binding affinity is modulated in accordance with the requirements of the expected therapeutic or diagnostic use of the molecule, preferably, the achievement

of greater specificity for TNF binding.

Alternatively, compounds having the structural and chemical features suitable as anti-TNF therapeutics and diagnostics provide structural analogs with selective TNF affinity. Molecular modeling studies of TNF binding compounds, such as TNF receptors, anti-TNF antibodies, or other TNF binding molecules, using a program such as MACROMODEL®, INSIGHT®, and DISCOVER® provide such spatial requirements and orientation of the anti-TNF Abs and/or peptides according to the present invention. Such structural analogs of the present invention thus provide selective qualitative and quantitative anti-TNF activity *in vitro, in situ* and/or *in vivo*.

Therapeutic Methods for Treating TNF-Related Pathologies The anti-TNF peptides, antibodies, fragments and/or derivatives of the present invention are useful for treating a subject having a pathology or condition associated with abnormal levels of a substance reactive with an anti-TNF antibody, in particular TNF, such as TNFα or TNFβ, in excess of, or less than, levels present in a normal healthy subject, where such excess or diminished levels occur in a systemic, localized or particular tissue type or location in the body. Such tissue types can include, but are not limited to, blood, lymph, CNS, liver, kidney, spleen, heart muscle or blood vessels, brain or spinal cord white matter or grey matter, cartilage, ligaments, tendons, lung, pancreas, ovary, testes, prostrate. Increased or decreased TNF concentrations relative to normal levels can also be localized to specific regions or cells in the body, such as joints, nerve blood vessel junctions, bones, specific tendons or ligaments, or sites of infection, such as bacterial or viral infections.

TNF related pathologies include, but are not limited to, the following:

(A) acute and chronic immune and autoimmune pathologies, such as systemic lupus erythematosus (SLE) rheumatoid arthritis, thyroidosis, graft versus host disease, scleroderma, diabetes mellitus, Graves' disease, and the

like;

(B) infections, including, but not limited to, sepsis syndrome, cachexia, circulatory collapse and shock resulting from acute or chronic bacterial infection, acute and chronic parasitic and/or infectious diseases, bacterial, viral or fungal, such as a HIV, AIDS (including symptoms of cachexia, autoimmune disorders, AIDS dementia complex and infections);

(C) inflammatory diseases, such as chronic inflammatory pathologies and vacsular inflammatory pathologies, including chronic inflammatory pathologies such as sarcoidosis, chronic inflammatory bowel disease, ulcerative colitis, and Crohn's pathology and vascular inflammatory pathologies, such as, but not limited to, disseminated intravascular coagulation, atherosclerosis, and Kawasaki's pathology:

(D) neurodegenerative diseases, including, but are not limited to,

demyelinating diseases, such as multiple sclerosis and acute transverse myelitis;

extrapyramidal and cerebellar disorders' such as lesions of the corticospinal system;

disorders of the basal ganglia or cerebellar disorders;

hyperkinetic movement disorders such as Huntington's Chorea and senile chorea;

drug-induced movement disorders, such as those induced by drugs which block CNS dopamine receptors;

hypokinetic movement disorders, such as Parkinson's disease;

Progressive supranucleo palsy;

Cerebellar and Spinocerebellar Disorders, such as astructural lesions of the cerebellum;

spinocerebellar degenerations (spinal ataxia, Friedreich's ataxia, cerebellar cortical degenerations, multiple systems degenerations

(Mencel, Dejerine-Thomas, Shi-Drager, and Machado-Joseph); and systemic disorders (Refsum's disease, abetalipoprotemia, ataxia, telangiectasia, and mitochondrial multi.system disorder); demyelinating core disorders, such as multiple sclerosis, acute transverse myelitis; disorders of the motor unit, such as neurogenic muscular atrophies (anterior horn cell degeneration, such as amyotrophic lateral sclerosis, infantile spinal muscular atrophy and juvenile spinal muscular atrophy); Alzheimer's disease; Down's Syndrome in middle age; Diffuse Lewy body disease; Senile Dementia of Lewy body type; Wernicke-Korsakoff syndrome; chronic alcoholism; Creutzfeldt-Jakob disease; Subacute sclerosing panencephalitis, Hallerrorden-Spatz disease; and Dementia pugilistica, or any subset thereof;

(E) malignant pathologies involving TNF-secreting tumors or other malignancies involving TNF, such as, but not limited to leukemias (acute, chronic myelocytic, chronic lymphocytic and/or myelodyspastic syndrome); lymphomas (Hodgkin's and non-Hodgkin's lymphomas, such as malignant lymphomas (Burkitt's lymphoma or Mycosis fungoides)); and

(F) alcohol-induced hepatitis.

See, e.g., Berkow et al, eds., The Merck Manual, 16th edition, chapter 11, pp 1380-1529, Merck and Co., Rahway, N.J., 1992, which reference, and references cited therein, are entirely incorporated herein by reference.

Such treatment comprises parenterally administering a single or multiple doses of the antibody, fragment or derivative. Preferred for human pharmaceutical use are high affinity potent hTNFα-inhibiting and/or neutralizing murine and chimeric antibodies, fragments and regions of this invention.

Anti-TNF peptides or MAbs of the present invention can be administered by any means that enables the active

agent to reach the agent's site of action in the body of a mammal. In the case of the antibodies of this invention, the primary focus is the ability to reach and bind with TNF released by monocytes and macrophages or other TNF producing cells. Because proteins are subject to being digested when administered orally, parenteral administration, i.e., intravenous, subcutaneous, intramuscular, would ordinarily be used to optimize absorption.

Therapeutic Administration

Anti-TNF peptides and/or MAbs of the present invention can be administered either as individual therapeutic agents or in combination with other therapeutic agents. They can be administered alone, but are generally administered with a pharmaceutical carrier selected on the basis of the chosen route of administration and standard pharmaceutical practice.

The dosage administered will, of course, vary depending upon known factors such as the pharmacodynamic characteristics of the particular agent, and its mode and route of administration; age, health, and weight of the recipient; nature and extent of symptoms, kind of concurrent treatment, frequency of treatment, and the effect desired. Usually a daily dosage of active ingredient can be about 0.01 to 100 milligrams per kilogram of body weight. Ordinarily 1.0 to 5, and preferably 1 to 10 milligrams per kilogram per day given in divided doses 1 to 6 times a day or in sustained release form is effective to obtain desired results.

As a non-limiting example, treatment of TNF-related pathologies humans or animals can be provided as a daily dosage of anti-TNF peptides, monoclonal chimeric and/or murine antibodies of the present invention 0.1 to 100 mg/kg, such as 0.5, 0.9, 1.0, 1.1, 1.5, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 40, 45, 50, 60, 70, 80, 90 or 100 mg/kg, per day, on at least one of day 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39,

or 40, or alternatively, at least one of week 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 or 20, or any combination thereof, using single or divided doses of every 24, 12, 8, 6, 4, or 2 hours, or any combination thereof.

Since circulating concentrations of TNF tend to be extremely low, in the range of about 10 pg/ml in non-septic individuals, and reaching about 50 pg/ml in septic patients and above 100 pg/ml in the sepsis syndrome (Hammerle, A.F. et al., 1989, *infra*) or can be only be detectable at sites of TNF-mediated pathology, it is preferred to use high affinity and/or potent *in vivo* TNF-inhibiting and/or neutralizing antibodies, fragments or regions thereof, for both TNF immunoassays and therapy of TNF-mediated pathology. Such antibodies, fragments, or regions, will preferably have an affinity for hTNFα, expressed as Ka, of at least 10^8 M^{-1}, more preferably, at least 10^9 M^{-1}, such as 10^8-10^{10} M^{-1}, 5 X 10^8 M^{-1}, 8 X 10^8 M^{-1}, 2 X 10^9 M^{-1}, 4 X 10^9 M^{-1}, 6 X 10^9 M^{-1}, 8 X 10^9 M^{-1}, or any range or value therein.

Preferred for human therapeutic use are high affinity murine and chimeric antibodies, and fragments, regions and derivatives having potent *in vivo* TNFα-inhibiting and/or neutralizing activity, according to the present invention, that block TNF-induced IL-6 secretion. Also preferred for human therapeutic uses are such high affinity murine and chimeric anti-TNFα antibodies, and fragments, regions and derivatives thereof, that block TNF-induced procoagulant activity, including blocking of TNF-induced expression of cell adhesion molecules such as ELAM-1 and ICAM-1 and blocking of TNF mitogenic activity, *in vivo*, *in situ*, and *in vitro*.

Dosage forms (composition) suitable for internal administration generally contain from about 0.1 milligram to about 500 milligrams of active ingredient per unit. In these pharmaceutical compositions the active ingredient will ordinarily be present in an amount of about 0.5-95% by weight

based on the total weight of the composition.

For parenteral administration, anti-TNF peptides or antibodies can be formulated as a solution, suspension, emulsion or lyophilized powder in association with a pharmaceutically acceptable parenteral vehicle. Examples of such vehicles are water, saline, Ringer's solution, dextrose solution, and 5% human serum albumin. Liposomes and nonaqueous vehicles such as fixed oils can also be used. The vehicle or lyophilized powder can contain additives that maintain isotonicity (e.g., sodium chloride, mannitol) and chemical stability (e.g., buffers and preservatives). The formulation is sterilized by commonly used techniques.

Suitable pharmaceutical carriers are described in the most recent edition of Remington's Pharmaceutical Sciences, A. Osol, a standard reference text in this field of art.

For example, a parenteral composition suitable for administration by injection is prepared by dissolving 1.5% by weight of active ingredient in 0.9% sodium chloride solution.

Anti-TNF peptides and/or antibodies of this invention can be adapted for therapeutic efficacy by virtue of their ability to mediate antibody-dependent cellular cytotoxicity (ADCC) and/or complement-dependent cytotoxicity (CDC) against cells having TNF associated with their surface. For these activities, either an endogenous source or an exogenous source of effector cells (for ADCC) or complement components (for CDC) can be utilized. The murine and chimeric antibodies, fragments and regions of this invention, their fragments, and derivatives can be used therapeutically as immunoconjugates (see for review: Dillman, R.O., Ann. Int. Med. 111:592-603 (1989)). Such peptides or Abs can be coupled to cytotoxic proteins, including, but not limited to ricin-A, Pseudomonas toxin and Diphtheria toxin. Toxins conjugated to antibodies or other ligands or peptides are well known in the art (see, for example, Olsnes, S. et al., *Immunol. Today* 10:291-295 (1989)). Plant and bacterial toxins typically kill cells by disrupting the protein

synthetic machinery.

Anti-TNF peptides and/or antibodies of this invention can be conjugated to additional types of therapeutic moieties including, but not limited to, radionuclides, therapeutic agents, cytotoxic agents and drugs. Examples of radionuclides which can be coupled to antibodies and delivered in vivo to sites of antigen include ^{212}Bi, ^{131}I, ^{186}Re, and ^{90}Y, which list is not intended to be exhaustive. The radionuclides exert their cytotoxic effect by locally irradiating the cells, leading to various intracellular lesions, as is known in the art of radiotherapy.

Cytotoxic drugs which can be conjugated to anti-TNF peptides and/or antibodies and subsequently used for in vivo therapy include, but are not limited to, daunorubicin, doxorubicin, methotrexate, and Mitomycin C. Cytotoxic drugs interfere with critical cellular processes including DNA, RNA, and protein synthesis. For a description of these classes of drugs which are well known in the art, and their mechanisms of action, see Goodman, et al., *Goodman and Gilman's THE PHARMACOLOGICAL BASIS OF THERAPEUTICS*, 8th Ed., Macmillan Publishing Co., 1990.

Anti-TNF peptides and/or antibodies of this invention can be advantageously utilized in combination with other monoclonal or murine and chimeric antibodies, fragments and regions , or with lymphokines or hemopoietic growth factors, etc., which serve to increase the number or activity of effector cells which interact with the antibodies.

Anti-TNF peptides and/or antibodies, fragments or derivatives of this invention can also be used in combination with TNF therapy to block undesired side effects of TNF. Recent approaches to cancer therapy have included direct administration of TNF to cancer patients or immunotherapy of cancer patients with lymphokine activated killer (LAK) cells (Rosenberg et al., *New Eng. J. Med.* 313:1485-1492 (1985)) or tumor infiltrating lymphocytes (TIL) (Kurnick et al. (*Clin. Immunol. Immunopath.* 38:367-380 (1986); Kradin et al., *Cancer*

Immunol. Immunother. 24:76-85 (1987); Kradin et al., *Transplant. Proc.* 20:336-338 (1988)). Trials are currently underway using modified LAK cells or TIL which have been transfected with the TNF gene to produce large amounts of TNF. Such therapeutic approaches are likely to be associated with a number of undesired side effects caused by the pleiotropic actions of TNF as described herein and known in the related arts. According to the present invention, these side effects can be reduced by concurrent treatment of a subject receiving TNF or cells producing large amounts of TIL with the antibodies, fragments or derivatives of the present invention. Effective doses are as described above. The dose level will require adjustment according to the dose of TNF or TNF-producing cells administered, in order to block side effects without blocking the main anti-tumor effect of TNF. One of ordinary skill in the art will know how to determine such doses without undue experimentation.

Treatment of Arthritis. In rheumatoid arthritis, the main presenting symptoms are pain, stiffness, swelling, and loss of function (Bennett JC. The etiology of rheumatoid arthritis. In Textbook of Rheumatology (Kelley WN, Harris ED, Ruddy S, Sledge CB, eds.) WB Saunders, Philadelphia pp 879-886, 1985). The multitude of drugs used in controlling such symptoms seems largely to reflect the fact that none is ideal. Although there have been many years of intense research into the biochemical, genetic, microbiological, and immunological aspects of rheumatoid arthritis, its pathogenesis is not completely understood, and none of the treatments clearly stop progression of joint destruction (Harris ED. Rheumatoid Arthritis: The clinical spectrum. In Textbook of Rheumatology (Kelley, et al., eds.) WB Saunders, Philadelphia pp 915-990, 1985).

TNFα is of major importance in the pathogenesis of rheumatoid arthritis. TNFα is present in rheumatoid arthritis joint tissues and synovial fluid at the protein and mRNA level (Buchan G, Barrett K, Turner M, Chantry D, Maini RN, and Feldmann M. Interleukin-1 and tumour necrosis factor

mRNA expression in rheumatoid arthritis: prolonged production of IL-1_{α}. *Clin. Exp. Immunol* 73: 449-455, 1988), indicating local synthesis. However detecting TNFα in rheumatoid arthritis joints even in quantities sufficient for bioactivation does not necessarily indicate that it is important in the pathogenesis of rheumatoid arthritis, nor that it is a good candidate therapeutic target. In order to address these questions, the effects of anti-TNF antibody and peptides (rabbit or monoclonal) on rheumatoid joint cell cultures, and for comparison, osteoarthritic cell cultures, have been studied. IL-1 production was abolished, showing TNFα as a suitable therapeutic target for the therapy of rheumatoid arthritis, since anti-TNFα blocks both TNF and IL-1, the two cytokines known to be involved in cartilage and bone destruction (Brennan et al., *Lancet* 11: 244-247, 1989).

Subsequent studies in rheumatoid arthritis tissues have supported this hypothesis. Anti-TNF Abs abrogated the production of another proinflammatory cytokine, GM-CSF (Haworth et al., *Eur. J. Immunol.* 21:2575-2579, 1991). This observation has been independently confirmed (Alvaro-Gracia et al., 1991). It has also been demonstrated that anti-TNF diminishes cell adhesion and HLA class II expression in rheumatoid arthritis joint cell cultures.

Diagnostic Methods

The present invention also provides the above anti-TNF peptides and antibodies, detectably labeled, as described below, for use in diagnostic methods for detecting TNFα in patients known to be or suspected of having a TNFα-mediated condition.

Anti-TNF peptides and/or antibodies of the present invention are useful for immunoassays which detect or quantitate TNF, or anti-TNF antibodies, in a sample. An immunoassay for TNF typically comprises incubating a biological sample in the presence of a detectably labeled high affinity anti-TNF peptide and/or antibody of the present invention capable of selectively binding to TNF, and detecting the labeled peptide or antibody which is bound in a

sample. Various clinical assay procedures are well known in the art, e.g., as described in *Immunoassays for the 80's*, A. Voller et al., eds., University Park, 1981.

Thus, an anti-TNF peptide or antibody, can be added to nitrocellulose, or other solid support which is capable of immobilizing cells, cell particles or soluble proteins. The support can then be washed with suitable buffers followed by treatment with the detectably labeled TNF-specific peptide or antibody. The solid phase support can then be washed with the buffer a second time to remove unbound peptide or antibody. The amount of bound label on the solid support can then be detected by known method steps.

By "solid phase support" or "carrier" is intended any support capable of binding peptide, antigen or antibody. Well-known supports or carriers, include glass, polystyrene, polypropylene, polyethylene, dextran, nylon, amylases, natural and modified celluloses, polyacrylamides, agaroses, and magnetite. The nature of the carrier can be either soluble to some extent or insoluble for the purposes of the present invention. The support material can have virtually any possible structural configuration so long as the coupled molecule is capable of binding to TNF or an anti-TNF antibody. Thus, the support configuration can be spherical, as in a bead, or cylindrical, as in the inside surface of a test tube, or the external surface of a rod. Alternatively, the surface can be flat such as a sheet, culture dish, test strip, etc. Preferred supports include polystyrene beads. Those skilled in the art will know many other suitable carriers for binding antibody, peptide or antigen, or can ascertain the same by routine experimentation.

Well known method steps can determine binding activity of a given lot of anti-TNF peptide and/or antibody. Those skilled in the art can determine operative and optimal assay conditions by routine experimentation.

Detectably labeling a TNF-specific peptide and/or antibody can be accomplished by linking to an enzyme for use in an enzyme immunoassay (EIA), or enzyme-linked

immunosorbent assay (ELISA). The linked enzyme reacts with the exposed substrate to generate a chemical moiety which can be detected, for example, by spectrophotometric, fluorometric or by visual means. Enzymes which can be used to detectably label the TNF-specific antibodies of the present invention include, but are not limited to, malate dehydrogenase, staphylococcal nuclease, delta-5-steroid isomerase, yeast alcohol dehydrogenase, alpha-glycerophosphate dehydrogenase, triose phosphate isomerase, horseradish peroxidase, alkaline phosphatase, asparaginase, glucose oxidase, beta-galactosidase, ribonuclease, urease, catalase, glucose-6-phosphate dehydrogenase, glucoamylase and acetylcholinesterase.

By radioactively labeling the TNF-specific antibodies, it is possible to detect TNF through the use of a radioimmunoassay (RIA) (see, for example, Work, et al., *Laboratory Techniques and Biochemistry in Molecular Biology*, North Holland Publishing Company, N.Y. (1978). The radioactive isotope can be detected by such means as the use of a gamma counter or a scintillation counter or by autoradiography. Isotopes which are particularly useful for the purpose of the present invention are: ^{3}H, ^{125}I, ^{131}I, ^{35}S, ^{14}C, and, preferably, ^{125}I.

It is also possible to label the TNF-specific antibodies with a fluorescent compound. When the fluorescent labeled antibody is exposed to light of the proper wave length, its presence can then be detected due to fluorescence. Among the most commonly used fluorescent labelling compounds are fluorescein isothiocyanate, rhodamine, phycoerythrin, phycocyanin, allophycocyanin, o-phthaldehyde and fluorescamine.

The TNF-specific antibodies can also be detectably labeled using fluorescence-emitting metals such as ^{152}Eu, or others of the lanthanide series. These metals can be attached to the TNF-specific antibody using such metal chelating groups as diethylenetriaminepentaacetic acid (DTPA) or ethylenediamine-tetraacetic acid (EDTA).

The TNF-specific antibodies also can be detectably labeled by coupling to a chemiluminescent compound. The presence of the chemiluminescently labeled antibody is then determined by detecting the presence of luminescence that arises during the course of a chemical reaction. Examples of particularly useful chemiluminescent labeling compounds are luminol, isoluminol, theromatic acridinium ester, imidazole, acridinium salt and oxalate ester.

Likewise, a bioluminescent compound can be used to label the TNF-specific antibody, fragment or derivative of the present invention. Bioluminescence is a type of chemiluminescence found in biological systems in which a catalytic protein increases the efficiency of the chemiluminescent reaction. The presence of a bioluminescent protein is determined by detecting the presence of luminescence. Important bioluminescent compounds for purposes of labeling are luciferin, luciferase and aequorin.

Detection of the TNF-specific antibody, fragment or derivative can be accomplished by a scintillation counter, for example, if the detectable label is a radioactive gamma emitter, or by a fluorometer, for example, if the label is a fluorescent material. In the case of an enzyme label, the detection can be accomplished by colorometric methods which employ a substrate for the enzyme. Detection can also be accomplished by visual comparison of the extent of enzymatic reaction of a substrate in comparison with similarly prepared standards.

For the purposes of the present invention, the TNF which is detected by the above assays can be present in a biological sample. Any sample containing TNF can be used. Preferably, the sample is a biological fluid such as, for example, blood, serum, lymph, urine, inflammatory exudate, cerebrospinal fluid, amniotic fluid, a tissue extract or homogenate, and the like. However, the invention is not limited to assays using only these samples, it being possible for one of ordinary skill in the art to determine suitable conditions which allow the use of other samples.

In situ detection can be accomplished by removing a histological specimen from a patient, and providing the combination of labeled antibodies of the present invention to such a specimen. The antibody (or fragment) is preferably provided by applying or by overlaying the labeled antibody (or fragment) to a biological sample. Through the use of such a procedure, it is possible to determine not only the presence of TNF but also the distribution of TNF in the examined tissue. Using the present invention, those of ordinary skill will readily perceive that any of a wide variety of histological methods (such as staining procedures) can be modified in order to achieve such *in situ* detection.

The antibody, fragment or derivative of the present invention can be adapted for utilization in an immunometric assay, also known as a "two-site" or "sandwich" assay. In a typical immunometric assay, a quantity of unlabeled antibody (or fragment of antibody) is bound to a solid support that is insoluble in the fluid being tested and a quantity of detectably labeled soluble antibody is added to permit detection and/or quantitation of the ternary complex formed between solid-phase antibody, antigen, and labeled antibody.

Typical, and preferred, immunometric assays include "forward" assays in which the antibody bound to the solid phase is first contacted with the sample being tested to extract the TNF from the sample by formation of a binary solid phase antibody-TNF complex. After a suitable incubation period, the solid support is washed to remove the residue of the fluid sample, including unreacted TNF, if any, and then contacted with the solution containing a known quantity of labeled antibody (which functions as a "reporter molecule"). After a second incubation period to permit the labeled antibody to complex with the TNF bound to the solid support through the unlabeled antibody, the solid support is washed a second time to remove the unreacted labeled antibody. This type of forward sandwich assay can be a simple "yes/no" assay to determine whether TNF is present or can be made quantitative by comparing the measure of labeled

antibody with that obtained for a standard sample containing known quantities of TNF. Such "two-site" or "sandwich" assays are described by Wide (*Radioimmune Assay Method*, Kirkham, ed., Livingstone, Edinburgh, 1970, pp. 199-206).

Other type of "sandwich" assays, which can also be useful with TNF, are the so-called "simultaneous" and "reverse" assays. A simultaneous assay involves a single incubation step wherein the antibody bound to the solid support and labeled antibody are both added to the sample being tested at the same time. After the incubation is completed, the solid support is washed to remove the residue of fluid sample and uncomplexed labeled antibody. The presence of labeled antibody associated with the solid support is then determined as it would be in a conventional "forward" sandwich assay.

In the "reverse" assay, stepwise addition first of a solution of labeled antibody to the fluid sample followed by the addition of unlabeled antibody bound to a solid support after a suitable incubation period, is utilized. After a second incubation, the solid phase is washed in conventional fashion to free it of the residue of the sample being tested and the solution of unreacted labeled antibody. The determination of labeled antibody associated with a solid support is then determined as in the "simultaneous" and "forward" assays. In one embodiment, a combination of antibodies of the present invention specific for separate epitopes can be used to construct a sensitive three-site immunoradiometric assay.

TNF REMOVAL FROM SOLUTIONS

The murine and chimeric antibodies, fragments and regions, fragments, or derivatives of this invention, attached to a solid support, can be used to remove TNF from fluids or tissue or cell extracts. In a preferred embodiment, they are used to remove TNF from blood or blood plasma products. In another preferred embodiment, the murine and chimeric antibodies, fragments and regions are advantageously used in extracorporeal immunoadsorbent

devices, which are known in the art (see, for example, *Seminars in Hematology*, 26 (2 Suppl. 1) (1989)). Patient blood or other body fluid is exposed to the attached antibody, resulting in partial or complete removal of circulating TNF (free or in immune complexes), following which the fluid is returned to the body. This immunoadsorption can be implemented in a continuous flow arrangement, with or without interposing a cell centrifugation step. See, for example, Terman, et al., *J. Immunol.* 117:1971-1975 (1976).

Having now generally described the invention, the same will be further understood by reference to certain specific examples which are included herein for purposes of illustration only and are not intended to be limiting unless otherwise specified.

EXAMPLE I

Production a Mouse Anti-Human TNF mAb

To facilitate clinical study of TNF mAb a high-affinity potent inhibiting and/or neutralizing mouse anti-human TNF IgG1 mAb designated A2 was produced.

Female BALB/c mice, 10 weeks old, were obtained from the Jackson Laboratory (Bar Harbor, ME). Forty μg of purified *E. coli*-derived recombinant human TNF (rhTNF) emulsified with an equal volume of complete Freund's adjuvant (obtained from Difco Laboratories) in 0.4 ml was injected subcutaneously and intraperitoneally (i.p.) into a mouse. One week later, an injection of 5 μg of rhTNF in incomplete Freund's adjuvant was given i.p. followed by four consecutive i.p. injections of 10 μg of TNF without adjuvant. Eight weeks after the last injection, the mouse was boosted i.p. with 10 μg of TNF.

Four days later, the mouse was sacrificed, the spleen was obtained and a spleen cell suspension was prepared. Spleen cells were fused with cells of the

nonsecreting hybridoma, Sp2/0 (ATCC CRL1581), at a 4:1 ratio of spleen cells to Sp2/0 cells, in the presence of 0.3 ml of 30% polyethylene glycol, PEG 1450. After incubation at 37°C for 6 hours, the fused cells were distributed in 0.2 ml aliquots into 96-well plates at concentrations of 2 x 10^4 SP2/0 cells per well. Feeder cells, in the form of 5 x 10^4 normal BALB/c spleen cells, were added to each well.

The growth medium used consisted of RPMI-1640 medium, 10% heat-inactivated fetal bovine serum (FBS) (HYCLONE), 0.1 mM minimum essential medium (MEM) nonessential amino acids, 1 mM sodium pyruvate, 2mM L-glutamine, 100 U/ml penicillin, 100 μg/ml streptomycin (GIBCO Laboratories) and, for selection, hypoxanthine-aminopterin-thymidine (HAT) (Boehringer Mannheim). A solid-phase radioimmunoassay (RIA) was employed for screening supernatants for the presence of mAbs specific for rhTNFα. This assay is described in Example II, below. The background binding in this assay was about 500 cpm. A supernatant was considered positive if it yielded binding of 2000 cpm or higher.

Of 322 supernatants screened, 25 were positive by RIA. Of these 25, the one with the highest binding (4800 cpm) was designated A2. Positive wells were subcloned at limiting dilution on mouse feeder cells. Upon further analysis of the supernatants in neutralization assays, A2 was found to be the only positive clone showing potent inhibiting and/or neutralizing activity. Thus, the hybridoma line A2 was selected. This line was maintained in RPMI-1640 medium with 10% FBS (GIBCO), 0.1 mM nonessential amino acids, 1 mM sodium pyruvate, 2 mM L-glutamine, 100 U/ml penicillin and 100 μg/ml streptomycin.

Alternatively, anti-TNF antibodies which inhibit TNF biological activity can be screened by binding to peptide including at least 5 amino acids of residues 87-108 or both residues 59-80 and 87-108 of TNF (of SEQ ID NO:1) or combinations of peptides contained therein, which are used in place of the rTNF protein, as described above.

EXAMPLE II

Characterization of an Anti-TNF antibody of the present invention.

Radioimmunoassays

E. coli-derived rhTNF was diluted to 1 μg/ml in BCB buffer, pH 9.6, and 0.1 ml of the solution was added to each assay well. After incubation at 4°C overnight, the wells were washed briefly with BCB, then sealed with 1% bovine incubated with 40 pg/ml of natural (GENZYME, Boston, MA) or recombinant (SUNTORY, Osaka, Japan) human TNFα with varying concentrations of mAb A2 in the presence of 20 μg/ml cycloheximide at 39°C overnight. Controls included medium alone or medium + TNF in each well. Cell death was measured by staining with naphthol blue-black, and the results read spectrophotometrically at 630 nm. Absorbance at this wave length correlates with the number of live cells present.

It was found that A2 inhibited or neutralized the cytotoxic effect of both natural and rhTNF in a dose-dependent manner (Figure 3).

In another experiment, the specificity of this inhibiting and/or neutralizing activity was tested. A673/6 cells were seeded at 3 x 10^4 cells/well 20 hr before the TNF bioassay. Two-fold serial dilutions of rhTNF, *E. coli*-derived recombinant human lymphotoxin (TNFß), and *E. coli*-derived recombinant murine TNF were prepared. The A2 hybridoma supernatant was added to an equal volume of the diluted TNF preparations, and the mixtures were incubated at room temperature for 30 min. Aliquots of 0.1 ml were transferred to the wells containing A673/6 cells, 20 μg/ml of cycloheximide was added, and the cells were incubated at 39°C overnight. The cells were then fixed and stained for evaluation of cytotoxicity. The results indicate that mAb A2 specifically inhibited or neutralized the cytotoxicity of rhTNFα, whereas it had no effect on human lymphotoxin (TNFß) (Figure 4) or murine TNF (Figure 5).

Experiments were next performed to analyze the cross-reactivity of mAb A2 with TNF derived from non-human

primates. Monocytes isolated from B514 (baboon), J91 (cynomolgus) and RH383 (rhesus) blood by Ficoll gradient centrifugation and adherence, were incubated at 1 x 10^5 cells/well in RPMl 1640 medium with 5% FBS and 2 μg/ml of E. coli LPS for 3 or 16 hr at 37°C to induce TNF production. Supernatants from duplicate wells were pooled and stored at 4°C for less than 20 hr until the TNF bioassay was performed, as described above, using A673/6 cells. Two-fold dilutions of the culture supernatants were mixed with either medium or purified mAb A2 at a final concentration of 1 μg/ml, incubated at room temperature for 30 min and aliquots transferred to the indicator cells. The results showed that mAb A2 failed to significantly inhibit or neutralize the cytotoxic activity of TNF produced by baboon, cynomolgus and rhesus monkey monocytes.

A further experiment was conducted with chimpanzee TNF. Monocytes isolated from CH563 (chimpanzee) blood were incubated as described above to generate TNF-containing supernatants. The ability of 10 μg/ml of mAb A2 to inhibit or neutralize the bioactivity of these supernatants was assayed as above. Human TNF was used as a positive control. Results, shown in Figure 6, indicate that mAb A2 had potent inhibiting and/or neutralizing activity for chimpanzee TNF, similar to that for human TNF (Figure 7).

The inhibiting and/or neutralizing activity of mAb A2 was compared with three other murine mAbs specific for human TNF, termed TNF-1, TNF-2 and TNF-3, and a control mAb. Two-fold serial dilutions of purified mAbs were mixed with rhTNF (40 pg/ml), incubated at room temperature for 30 min, and aliquots tested for TNF bioactivity as above. It was found that mAbs TNF-1, TNF-2 and TNF-3 each had a similar moderate degree of inhibiting and/or neutralizing activity. In contrast, mAb A2 had much more potent inhibiting and/or neutralizing activity.

EXAMPLE III

General Strategy for Cloning Antibody V and C Genes

The strategy for cloning the V regions for the H and L chain genes from the hybridoma A2, which secretes the anti-TNF antibody described above, was based upon the linkage in the genome between the V region and the corresponding J (joining) region for functionally rearranged (and expressed) Ig genes. J region DNA probes can be used to screen genomic libraries to isolate DNA linked to the J regions. Although DNA in the germline configuration (i.e., unrearranged) would also hybridize to J probes, this DNA would not be linked to a Ig V region sequence and can be identified by restriction enzyme analysis of the isolated clones.

The cloning utilized herein was to isolate V regions from rearranged H and L chain genes using J_H and J_k probes. These clones were tested to see if their sequences were expressed in the A2 hybridoma by Northern analysis. Those clones that contained expressed sequence were cloned into expression vectors containing human C regions and transfected into mouse myeloma cells to determine if an antibody was produced. The antibody from producing cells was then tested for binding specificity and functionally compared to the A2 murine antibody.

EXAMPLE IV

Construction of a L Chain Genomic Library

To isolate the L chain V region gene from the A2 hybridoma, a size-selected genomic library was constructed using the phage lambda vector charon 27. High molecular weight DNA was isolated from A2 hybridoma cells and digested to completion with restriction endonuclease HindIII. The DNA was then fractionated on a 0.8% agarose gel and the DNA fragments of three different size ranges of approximately 3 kb, 4 kb and 6 kb were isolated from the gel by electroelution. The size ranges for library construction were chosen based upon the size of Hind III fragments that

hybridized on a southern blot with the J_k probe. After phenol/chloroform extraction and ethanol precipitation, the DNA fragments from each size class were ligated with lambda charon 27 arms and packaged into phage particles *in vitro* using Gigapack Gold from Stratagene (LaJolla, CA).

These libraries were screened directly at a density of approximately 20,000 plaques per 150 mm petri dish using a ^{32}P-labeled J_k probe. The mouse L chain J_k probe was a 2.7 kb HindIII fragment containing all five J_k segments. The probe was labeled with ^{32}P by random priming using a kit obtained from Boehringer Mannheim. Free nucleotides were removed by centrifugation through a Sephadex G-50 column. The specific activities of the probe was approximately 10^9 cpm/μg.

Plaque hybridizations were carried out in 5x SSC, 50% formamide, 2x Denhardt's reagent, and 200 μg/ml denatured salmon sperm DNA at 42°C for 18-20 hours. Final washes were in 0.5x SSC, 0.1% SDS at 65°C. Positive clones were identified after autoradiography.

EXAMPLE V

Construction of H Chain Genomic Library

To isolate the V region gene for the A2 H chain, a genomic library was constructed in the lambda gt10 vector system. High molecular weight DNA was digested to completion with restriction endonuclease EcoRI and fragments of approximately 7.5 kb were isolated after agarose gel electrophoresis. These fragments were ligated with lambda gt10 arms and packaged into phage particles *in vitro* using Gigapack Gold.

This library was screened at a density of 20,000 plaques per 150 mm plate using a J_H probe. The J_H probe was a 2kb BamHI/EcoRI fragment containing both J3 and J4 segments. The probe was labeled as in Example III and had a similar specific radioactivity. Hybridization and wash conditions were identical to those used in Example III.

EXAMPLE VI

Cloning of the TNF-Specific V gene regions

Several positive clones were isolated from the H and L chain libraries after screening approximately 10^6 plaques from each library using the J_H and J_k probes, respectively. Following plaque purification, bacteriophage DNA was isolated for each positive clone, digested with either EcoRI (H chain clones) or HindIII (L chain clones) and fractionated on 1% agarose gels. The DNA was transferred to nitrocellulose and the blots were hybridized with the J_H or the J_K probe.

Several H chain clones were obtained that contained 7.5 kb EcoRI DNA encoding fragments of MAbs to the J_H probe. For the light chain libraries, several clones from each of the three size-selected libraries were isolated that contained HindIII fragments that hybridize to the J_k probe. For the L chain, several independently derived HindIII fragments of 2.9 kb from the 2 kb library hybridized with a 1250 bp mRNA from A2, but not with SP2/0 mRNA (see Example VII). In addition, several HindIII fragments derived from the 4 kb library hybridized both to the A2 mRNA and the fusion partner mRNA. A 5.7 kb HindIII fragment from the 6 kb library did not hybridize to either RNA.

The observed lengths of hybridizing A2 mRNA were the correct sizes for H and L chain mRNA, respectively. Because the RNA expression was restricted to the A2 hybridoma, it was assumed that the 7.5 kb H chain fragments and the 2.9 kb L chain fragments contained the correct V region sequences from A2. One example of each type was chosen for further study. The important functional test is the demonstration that these V regions sequences, when combined with appropriate C region sequences, are capable of directing the synthesis of an antibody with a specificity and affinity similar to that of the murine A2 antibody.

The 7.5 kb H chain fragment and the 2.9 kb L chain fragment were subcloned into plasmid vectors that allow

expression of the chimeric mouse/human proteins in murine myeloma cells (see Examples VIII and IX). These plasmids were co-transfected into SP2/0 cells to ascertain if intact antibody molecules were secreted, and if so, if they were of the correct specificity and affinity. Control transfections were also performed pairing the putative anti-TNF H chain with an irrelevant, but expressed, L chain; the putative anti-TNF L chain was also paired with an irrelevant, but expressed, H chain. The results indicated that the 7.5 kb H chain fragment could be expressed, whereas the 2.9 kb L chain fragment could not. This was confirmed by DNA sequence analysis that suggested portions of the coding region were not in the proper amino acid reading frame when compared to other known L chain amino acid sequences.

Because the 2.9 kb HindIII fragment appeared not to contain a functional V gene, the 4.0 kb and 5.7 kb HindIII fragments isolated from L chain libraries were cloned into expression vectors and tested for expression of chimeric antibody after co-transfection with the 7.5 kb H chain. The 5.7 kb HindIII fragment was incapable of supporting antibody expression, whereas the 4.0 kb HindIII fragment did support antibody expression. The antibody resulting from the co-transfection of the 7.5 kb putative H chain V region and the 4.0 kb L chain V region was purified, tested in solid phase TNF binding assay, and found to be inactive. It was concluded that the V region contained on the 4.0 kb HindIII fragment was not the correct anti-TNF V regions, but was contributed to the hybridoma by the fusion partner. This was subsequently confirmed by sequence analysis of cDNA derived from the A2 hybridoma and from the fusion partner.

Other independently derived L chain clones containing 2.9 kb HindIII fragments that hybridized with A2 mRNA were characterized in more detail. Although the restriction maps were similar, the clones fell into two classes with respect tot the presence or absence of an AccI enzyme site. The original (non-functional) 2.9 kb fragment (designated clone 8.3) was missing an AccI site present in

some other clones (represented by clone 4.3). The DNA sequence of clone 4.3 was extremely similar to clone 8.3, but contained a single amino acid reading frame with close homology to known L chains, unlike clone 8.3. The 2.9 kb HindIII fragment from clone 4.3 was subcloned into the L chain expression vector and co-transfected with the putative anti-TNF H chain into SP2/0 cells. An antibody was synthesized, purified and tested in the solid phase TNF binding assay. This antibody bound to TNF, and therefore, the clone 4.3 L chain V region was assumed to be the correct one.

The A2 murine hybridoma has been shown to contain at least four rearranged L chain V region genes. At least two of these are expressed as proteins: clone 4.3 (the correct anti-TNF L chain gene) and the gene contained in the 4.0 kb HindIII fragment (contributed by the fusion partner). The expression of two L chains implies that the resulting antibody secreted from the murine hybridoma is actually a mixture of antibodies, some using the correct L chain, some using the incorrect L chain, and some using one of each. The presence of two different L chains in the murine A2 antibody has been confirmed by SDS gel and N-terminal protein sequence analysis of the purified antibody. Because construction of the chimeric A2 antibody involves cloning the individual H and L chain genes and expressing them in a non-producing cell line, the resulting antibody will have only the correct L chain and therefore should be a more potent antibody (see Examples X, XI and XII).

EXAMPLE VII

Northern Analysis of Cloned DNA

Cloned DNA corresponding to the authentic H and L chain V regions from the A2 hybridoma would be expected to hybridize to A2 mRNA. Non-functional DNA rearrangements at either the H or L chain genetic loci should not be expressed.

Ten μg total cellular RNA was subjected to

electrophoresis on 1% agarose/formaldehyde gels (Sambrook et al, infra) and transferred to nitrocellulose. Blots were hybridized with random primed DNA probes in 50% formamide, 2x Denhardt's solution, 5x SSC, and 200 μg/ml denatured salmon sperm DNA at 42°C for 10 hours. Final wash conditions were 0.5 x SSC, 0.1% SDS at 65°C.

The subcloned DNA fragments were labeled with ^{32}P by random priming and hybridized to Northern blots containing total RNA derived from A2 cells or from cells of SP2/0, the fusion partner parent of A2. The 7.5 kb EcoRI H chain fragment hybridized with a 2 kb mRNA from A2, but not with SP2/0 mRNA. Similarly, the 2.9 kb L chain HindIII fragment (clone 4.3) hybridized with a 1250 bp mRNA from A2, but not with SP2/0 mRNA. The observed lengths of A2 mRNA hybridizing were the correct sizes for H and L chain mRNA, respectively, confirming that the V region sequences on these DNA fragments are expressed in A2 hybridoma cells.

EXAMPLE VIII:

Construction of Expression Vectors

The putative L (clone 4.3) and H chain V genes described above were joined to human kappa and gamma1 constant region genes in expression vectors. The 7.5 kb EcoRI fragment corresponding to the putative V_H region gene from A2 was cloned into an expression vector containing the human C_{gamma1} gene and the Ecogpt gene to yield the plasmid designated pA2HG1apgpt (see Figure 8).

The 2.9 kb putative V_L fragment from clone 4.3 was cloned into a vector containing the human kappa C_k gene and the Ecogpt gene to allow selection in mammalian cells. The resulting plasmid was designated pA2HuKapgpt (See Figure 8).

EXAMPLE IX

Expression of Chimeric Antibody Genes

To express the chimeric H and L chain genes, the expression plasmids were transfected into cells of the non-producing mouse myeloma cell line, SP2/0. Plasmid DNA to be transfected was purified by centrifuging to equilibrium in ethidium bromide/cesium chloride gradients twice. Plasmid DNA (10-50 μg) was added to 10^7 SP2/0 cells in medium containing Hank's salts, and the mixture was placed in a BIORAD electroporation apparatus. Electroporation was performed at 20 volts, following which the cells were plated in 96 well microtiter plates.

Mycophenolic acid selection was applied after 24 hours and drug resistant colonies were identified after 1-2 weeks. Resistant colonies were expanded to stable cell lines and tissue culture supernatant from these cell lines was tested for antibody using an ELISA assay with goat anti-human IgG Fc antibody and goat anti-human H+L conjugated with alkaline phosphatase (obtained from Jackson Laboratories).

The chimeric A2 antibody was purified from tissue culture supernatant by Protein A- Sepharose chromatography. The supernatant was adjusted to 0.1M Tris, 0.002M EDTA, pH 8.0 and loaded on a Protein A-Sepharose column equilibrated in the same buffer. The IgG was eluted with 0.1M citrate, pH 3.5, inhibited or neutralized with 1M Tris, and dialyzed into phosphate buffered saline (PBS).

The purified chimeric antibody was evaluated for its binding and inhibiting and/or neutralizing activity.

EXAMPLE X

Specificity of an Anti-TNF Chimeric Antibody

Since the antigen binding domain of cA2 was derived from murine A2, these mAbs would be expected to compete for the same binding site on TNF. Fixed concentrations of chimeric A2 and murine mAb A2 were incubated with increasing concentrations of murine and chimeric A2 competitor, respectively, in a 96-well microtiter plate coated with rhTNF

(Dainippon, Osaka, Japan). Alkaline-phosphatase conjugated anti-human immunoglobulin and anti-mouse immunoglobulin second antibodies were used to detect the level of binding of chimeric and murine A2, respectively. Cross-competition for TNF antigen was observed in this solid-phase ELISA format (Figure 9). This finding is consistent with the expected identical epitope specificity of cA2 and murine A2.

The affinity constant for binding of mouse mAb A2 and cA2 to rhTNFα was determined by Scatchard analysis (see, for example, Scatchard, *Ann. N.Y. Acad. Sci.* 51:660 (1949)). The results are shown in Figure 10. This analysis involved measuring the direct binding of ^{125}I labelled cA2 to immobilized rhTNFα in a 96-well plate. The antibodies were each labelled to a specific activity of about 9.7 μCi/μg by the iodogen method. An affinity constant (Ka) of 0.5 x 10^9 liters/mole was calculated for the mouse mAb A2. Unexpectedly, the chimeric A2 antibody had a higher affinity, with a Ka of 1.8 x 10^9 liters/mole. Thus, the chimeric anti-TNFα antibody of the present invention was shown to exhibit a significantly higher affinity of binding to human TNFα than did the parental murine A2 mAb. This finding was surprising, since murine and chimeric antibodies, fragments and regions would be expected to have affinities that are equal to or less than that of the parent mAb.

Such high affinity anti-TNF antibodies, having affinities of binding to TNFα of at least 1 x 10^8 M^{-1}, more preferably at least 1 x 10^9 M^{-1} (expressed as Ka) are preferred for immunoassays which detect very low levels of TNF in biological fluids. In addition, anti-TNF antibodies having such high affinities are preferred for therapy of TNF-α-mediated conditions or pathology states.

The specificity of cA2 for TNF was confirmed by testing for cross-neutralization of human lymphotoxin (TNF-ß). Lymphotoxin shares some sequence homology and certain biological activities, for example, tumor cell cytotoxicity, with TNF (Pennica, et al., *Nature* 312:724-729

(1984)). Cultured human A673 cells were incubated with increasing concentrations of human lymphotoxin (GENENTECH, San Francisco, CA) with or without 4 μg/ml chimeric A2 in the presence of 20 μg/ml cycloheximide at 39°C overnight. Cell death was measured by vital staining with naphthol blue-black, as above. The results indicated that cA2 was ineffective at inhibiting and/or neutralizing human lymphotoxin, confirming the TNFα-specificity of the chimeric antibody.

The ability of A2 or cA2 to react with TNF from different animal species was also evaluated. As mentioned earlier, there are multiple epitopes on human TNF to which inhibiting and/or neutralizing mAbs will bind (Moller, et al., *infra*). Human TNF has bioactivity in a wide range of host animal species. However, certain inhibiting and/or neutralizing epitopes on human TNF are conserved amongst different animal species and others appear to be restricted to humans and chimpanzees.

Neutralization experiments utilized endotoxin-activated cell supernatants from freshly isolated human, chimpanzee, rhesus and cynomolgus monkey, baboon, pig, dog, rabbit, or rat monocytes as the TNF source. As discussed above, murine mAb A2 inhibited or neutralized activity of only human and chimpanzee TNF, and had no effect on TNF derived from other primates and lower animals. A2 also did not inhibit or neutralize the cytotoxic effect of recombinant mouse TNF.

Thus, the epitope recognized by A2 is one shared by human and chimpanzee TNFα. Chimeric A2 was also tested in this manner for cross-reactivity with monocyte-derived TNF from rat, rabbit, dog and pig, as well as with purified recombinant mouse TNFα, and natural and recombinant human TNFα. Chimeric A2 only inhibited or neutralized natural and recombinant human TNFα. Therefore, cA2 appears to share species specificity with murine A2.

EXAMPLE XI

In Vitro Activity and Neutralization Efficacy of a Chimeric Anti-TNF Antibody

Both the murine and chimeric anti-TNFα antibodies, A2 and cA2 were determined to have potent TNF-inhibiting and/or neutralizing activity. In the TNF cytotoxicity assay described above, murine A2, at a concentration of about 125 ng/ml completely inhibited or neutralized the biological activity of a 40 pg/ml challenge of rhTNFα. Two separate determinations of inhibiting and/or neutralizing potency, expressed as the 50% Inhibitory Dose (ID50) were determined to be 15.9 ± 1.01 and 17.9 ± 1.6 ng/ml (Mean ± Std error). Thus the mAb A2 has an ID50 of about 17 ng/ml.

In this same experimental system, three other murine anti-TNFα antibodies (termed TNF-1, TNF-2 and TNF-3) of comparable binding affinity to TNF were found to have ID50 values of 1-2 orders of magnitude greater, and thus were significantly less potent in neutralization than A2.

The ability of cA2 to inhibit or neutralize human TNFα bioactivity *in vitro* was tested using the bioassay system described above. Cultured A673 cells were incubated with 40 pg/ml natural (Genzyme, Boston, MA) or recombinant (Suntory, Osaka, Japan) human TNF with or without antibody overnight as above, and cell death was measured by vital staining. As expected based upon the above results with the A2 mouse mAb, cA2 also inhibited or neutralized both natural and rhTNF in a dose-dependent manner in the cytotoxicity assay (Figure 11). In this assay format, levels of cA2 as low as 125 ng/ml completely abolished the toxic activity of TNF. Upon repeated analysis, the cA2 exhibited greater TNF-inhibiting and/or neutralizing activity than did the parent murine A2 mAb. Such inhibiting and/or neutralizing potency, at antibody levels below 1 μg/ml, can easily be attained in the blood of a subject to whom the antibody is administered. Accordingly, such highly potent inhibiting and/or neutralizing anti-TNF antibodies, in particular the chimeric antibody, are preferred for therapeutic use in

TNFα-mediated pathologies or conditions.

As mentioned above, TNF induces cellular secretion of IL-6. Furthermore, there is evidence that IL-6 is involved in the pathophysiology of sepsis, although the precise role of IL-6 in that syndrome is unclear (Fong, et al., *J Exp Med* 170:1627-1633 (1989); Starnes Jr., et al., *J Immunol* 145:4185-4191 (1990)). The ability of cA2 to inhibit or neutralize TNF-induced IL-6 secretion was evaluated using cultured human diploid FS-4 fibroblasts. The results in Table 2 show that cA2 was effective in blocking IL-6 secretion in cells that had been incubated overnight with TNF. TNF-induced IL-6 secretion was not inhibited in the absence of a mAb or in the presence of a control mAb specific for an irrelevant antigen.

TABLE 2

IN VITRO NEUTRALIZATION OF TNF-INDUCED IL-6 SECRETION

	TNF Concentration (ng/ml)			
Antibody	0	0.3	1.5	7.5
None	<0.20	1.36	2.00	2.56
Control mAb	<0.20	1.60	1.96	2.16
cA2	<0.20	<0.20	<0.20	0.30

Values represent mean concentrations of IL-6 of duplicate wells, in ng/ml. RhTNF (Suntory, Osaka, Japan), with or without 4 μg/ml antibody, was added to cultures of FS-4 fibroblasts and after 18 h, the supernatant was assayed for IL-6 using the QUANTIKINE Human IL-6 Immunoassay (from R&D Systems, Minneapolis, MN). Control mAb = chimeric mouse/human IgG1 anti-platelet mAb (7E3).

The ability of TNF to activate procoagulant and adhesion molecule activities of endothelial cells (EC) is thought to be an important component of pathology pathophysiology. In particular, this can be associated with the vascular damage, disseminated intravascular coagulation,

and severe hypotension that is associated with the sepsis syndrome. Therefore, the ability of cA2 to block TNF-induced activation of cultured human umbilical vein endothelial cells (HUVEC) was evaluated. TNF stimulation of procoagulant activity was determined by exposing intact cultured HUVEC cells to TNF (with or without antibody) for 4 hours and analyzing a cell lysate in a human plasma clotting assay. The results in Table 3 show the expected upregulation by TNF of HUVEC procoagulant activity (reflected by a decreased clotting time). Chimeric antibody cA2 effectively inhibited or neutralized this TNF activity in a dose-dependent manner.

TABLE 3

IN VITRO NEUTRALIZATION OF TNF-INDUCED PROCOAGULANT ACTIVITY

		TNF Concentration (ng/ml)		
Antibody	μg/ml	250	25	0
None	-	64 ± 4*	63 ± 1	133 ± 13
Control Ab	10.00	74 ± 6	N.D.	178 ± 55
cA2	10.00	114 ± 5	185 ± 61	141 ± 18
cA2	3.30	113 ± 2	147 ± 3	N.D.
cA2	1.10	106 ± 1	145 ± 8	N.D.
A2	0.37	73 ± 17	153 ± 4	N.D.
cA2	0.12	64 ± 1	118 ± 13	N.D.

* Values represent mean plasma clotting time, in seconds (± S.D.). Clotting time was determined in normal human plasma after addition of the rhTNF (Dainippon, Osaka, Japan) with or without antibody-treated HUVEC lysate and Ca^{++} at 37°C. N.D. = Not done. Control Ab is a chimeric mouse/human IgG1 anti-CD4 antibody.

In addition to stimulating procoagulant activity, TNF also induces surface expression of endothelial cell

adhesion molecules such as ELAM-1 and ICAM-1. The ability of cA2 to inhibit or neutralize this activity of TNF was measured using an ELAM-1 specific detection radioimmunoassay. Cultured HUVEC were stimulated with 250 ng/ml rhTNF (Dainippon, Osaka, Japan) with or without antibody at 37°C overnight in a 96-well plate format. Surface expression of ELAM-1 was determined by sequential addition of a mouse anti-human ELAM-1 mAb and ^{125}I-labelled rabbit anti-mouse immunoglobulin second antibody directly to culture plates at 4°C.

As shown in Figure 12, TNF induced the expression of ELAM-1 on the surface of cultured HUVEC cells, and this activity was again effectively blocked in a dose-related manner by cA2.

Finally, TNF is known to stimulate mitogenic activity in cultured fibroblasts. Chimeric A2 inhibited or neutralized TNF-induced mitogenesis of human diploid FS-4 fibroblasts cultures, confirming the potent inhibiting and/or neutralizing capability of cA2 against a broad spectrum of in vitro TNF biological activities.

EXAMPLE XII:

Determination of amino acid sequences (epitope) on human TNF-α recognized by cA2 mAb

Reagents The following reagents are readily available from commercial sources. FMOC-L-Ala-OPfp, FMOC-L-Cys(Trt)-OPfp, FMOC-L-Asp(OtBu)-OPfp, FMOC-L-Glu(OtBu)-OPfp, FMOC-L-Phe-OPfp, FMOC-Gly-OPfp, FMOC-L-His(Boc)-OPfp, FMOC-L-Ile-OPfp, FMOC-L-Lys(Boc)-OPfp, FMOC-L-Leu-OPfp, FMOC-L-Asn-OPfp, FMOC-L-Pro-OPfp, FMOC-L-Gln-OPfp, FMOC-L-Arg(Mtr)-OPfp, FMOC-L-Ser(tBu)-ODhbt, FMOC-L-Thr(tBu)-ODhbt, FMOC-L-Val-OPfp, FMOC-L-Trp-OPfp, FMOC-L-Try(tBu)-OPfp, and 1-hydroxybenotriazol (HOBT) were obtained from Cambridge Research Biochemicals. Piperidine and was obtained from Applied Biosystems, Inc. 1-Methyl-2-Pyrrolidinone (NMP) was obtained from EM Science; Methanol from JT Baker; Acetic

Anhydride from Applied Biosystems, Inc., Trifluoroaccetic acid (TFA) from Applied Biosystems, Inc.; Diisopropylamne (DIEA), Triethylamine, Dithiothreitol (DTT) and Anisole from Aldrich and Hydrochloric Acid (HCl) from JT Baker.

Abbreviations: FMOC, 9-fluorenylmethoxycarbonyl; tBu t-butyl ether; OtB, t-butyl ester; Boc, t-butyloxycarbonyl; Mtr, 4-methoxy-2,3,6-trimethylbenzenesulfonyl; Trt, trityl; OPfp, pentafluorophenylester; ODhbt. oxo-benzotriazone ster;

A chimeric antibody of the present invention, designated cA2, was used to determine which portions of the TNF amino acid sequence were involved in inhibitory binding by the antibody by epitope mapping, whereby the amino acid sequences of TNF-α recognized by cA2 have been identified.

The complete primary sequence of human TNFα, according to Pennica et al, Nature 312:724-729 (1984) is shown in Figure 13 (SEQ ID NO:1). Overlapping decapeptides beginning with every second amino acid and covering the entire amino acid sequence of human TNF-α were synthesized on polyethylene pins using the method of Gysen (Gysen et al., Peptides: Chemistry and Biological, Proceedings of the Twelfth American Peptide Symposium, p. 519-523, Ed, G.R. Marshall, Escom, Leiden, 1988). Sets of peptide pins bearing free N-terminal amino groups and acetylated N-terminal amino groups were individually prepared. Both sets of peptide pins were incubated in solutions containing the anti-TNF mAb cA2 to determine the amino acid sequences that make up the cA2 epitope on human TNF-α, as described below. Figure 14A shows the results of binding to the overlapping decapeptides that comprise the entire sequence of human TNFα. The O.D. (optional density) correlates directly with the increased degree of cA2 binding. Figure 14B shows the results of binding of cA2 to the same set of peptide pins in the presence of human TNFα. This competitive binding study delineates peptides which can show non-specific binding to cA2.

There are at least two non-contiguous peptide

sequences of TNF-α recognized by cA2. Using the conventional protein numbering system wherein the N-terminal amino acid is number 1, the cA2 mAb recognizes an epitope composed at least in part of amino acids located within residues 87-108 or both residues 59-80 and 87-108 of TNF (SEQ ID NO:1). Figure 15 presents these non-contiguous sequences within the TNF sequence. These sequences are also shown in a space filling model in Figure 16B, along with a space filing model of the TNF monomer shown in Figure 16A.

Unexpectedly, the mAb cA2 blocks the action of TNF-α without binding to the putative receptor binding locus, which can include one or more of, e.g., 11-13, 37-42, 49-57 or 155-157 of hTNFα (of SEQ ID NO:1). Preferred anti-TNF mAbs are those that inhibit this binding of human TNF-α to its receptors by virtue of their ability to bind to one or more of these peptide sequences. These antibodies can block the activity of TNF by virtue of binding to the cA2 epitope, such binding demonstrated to inhibit TNF activity. The identification of those peptide sequences recognized by cA2 provides the information necessary to generate additional MAbs with binding characteristics and therapeutic utility that parallel the embodiments of this application.

Peptide Pin Synthesis. Using an epitope mapping kit purchased from Cambridge Research Biochemicals, Inc. (CRB), dodecapeptides corresponding to the entire sequence of human TNF-α were synthesized on polyethylene pins.

A synthesis schedule was generated using the CRB epitope mapping software. Prior to the first amino acid coupling, the pins were deprotected with a 20% piperidine in NMP solution for 30 minutes at room temperature. After deprotected, the pins were washed with NMP for five minutes at room temperature, followed by three methanol washes. Following the wash steps, the pins were allowed to air dry for at least 10 minutes.

The following procedure was performed for each coupling cycle:

1) The amino acid derivatives and the HOBT were

weighted out according to the weights required in the synthesis schedule.

2) The HOBT was dissolved in the appropriate amount of NMP according to the synthesis schedule.

3) The amino acid derivatives were dissolved in the recommended amount of HOBT solution and 150 microliters were pipeted into the appropriate wells as directed by the well position sheet of the synthesis schedule.

4) The blocks containing the pins were placed into the wells, and the "sandwich" units stored in plastic bags in a 30°C water bath for 18 hours.

5) The pins were removed from the wells and washed once (for 5 minutes) with NMP, three times (for two minutes) with methanol and air dried for 10 minutes.

6) The pins were deprotected as described above and the procedure repeated.

To acetylate the peptides on one block of pins, the peptide pins were washed, deprotected and treated with 150 microliters of a solution containing NMP; acetic anhydride:triethylamine (5:2:1) for 90 minutes at 30°C, followed by the washing procedure outlined above. The second set of peptide pins was deprotected by not acetylated to give free N-terminal amino groups.

The final deprotection of the peptides to remove the side chain protecting groups was done using a mixture of TFA:anisole:dithiothreitol, 95:2.5:2.5 (v/v/w) for four hours at ambient temperature. After deprotection, the pins were air dried for 10 minutes, followed by a 15 minute sonication in a solution of 0.1% HCl in methanol/distilled water (1:1). The pins dried over night and were then ready for testing.

ELISA Assay for cA2 Binding to TNF-α Peptide PINs

Reagents: Disruption Buffer: Sodium dihydrogen phosphate (31.2 g, Sigma cat # S-0751 or equivalent) and sodium dodecylsulfate (20.0 g, Sigma cat # L-3771 or equivalent) were dissolved in 2.0 L of milliQ water. The pH was adjusted to 7.2 ± 0.1 with 50% w/w sodium hydroxide (VWR cat # VW6730-3 or equivalent).

Blocking Buffer: Sodium dihydrogen phosphate (0.39 g, Sigma cat #S-0751 or equivalent) disodium hydrogen phosphate (1.07 g, Baker cat # 3828-1 or equivalent) and sodium chloride (8.50 g, Baker cat # 3624-5 or equivalent were dissolved in 1.0 L of milliQ water. The pH was adjusted to 7.2 ± 0.1 with 50% w/w sodium hydroxide (VWR cat VW6730-3 or equivalent). Chicken egg albumin (10.0 g, Sigma cat #A-5503 or equivalent) and bovine serum albumin (10.0 g, Sigma, cat #A-3294 or equivalent) were dissolved at room temperature with gentle stirring. The solution was filtered, and to the solution was added Tween 20 (2.0 ml, Sigma cat #P-13.79 or equivalent). The solution was stirred gently at room temperature for 30 min, filtered and stored at 40°.

PBS/Tween 20: A 10 x concentrate was prepared by dissolving sodium dihydrogen phosphate (3.90 g, Sigma cat # S-0751 or equivalent), disodium hydrogen phosphate (10.70 g, Baker cat #3828-1 or equivalent) and sodium chloride (85.0 g, Baker cat #3624-5 or equivalent) in 1.0 L of milliQ water. The pH was adjusted to 7.2 ± 0.1 with 50% w/w sodium hydroxide (VWR cat #VW 6730 or equivalent). To the solution was added Tween 20 (5.0 mL, Sigma cat #P-1379 or equivalent), and the mixture stirred gently. Just prior to use 100 mL of this solution was diluted to 1.0 L with milliQ water.

Substrate solution: Substrate buffer was prepared by dissolving citric acid (4.20g, Malinckrodt cat #0627 or equivalent) and disodium hydrogen phosphate (7.10 g, Baker cat #3828-1 or equivalent) in 1.0 L of milliQ water. The pH was adjusted to 5.00 with 50% w/w sodium hydroxide (VWR cat #VW6730-3 or equivalent). Immediately prior to use an OPD substrate tablet (30 mg, Sigma cat #P-8412 or equivalent and 30% (v/v) hydrogen peroxide (40 μL, Sigma cat #P-1379 or equivalent) were added to the substrate buffer 25.0 mL). The solution was wrapped in foil and mixed thoroughly.

4 NH_2SO_4; Sulfuric acid (53 mL, EM Science cat #SX1244-5 or equivalent) was slowly added to MILLI-Q water (447 mL) and cooled to room temperature prior to use.

Equipment: Molecular Devices Model nu-max plate

reader or equivalent. Scientific Products Model R4140 Oscillating table shaker and equivalent. BRANSON Model 5200 ultra-sonic bath or equivalent. FINNPIPETTE Model 4172317 multichannel pipeter or equivalent. CORNING Model 25801 96 well disposable polystyrene Elisa Plates.

Prior to use and after each subsequent use the peptide pins were cleaned using the following procedure. Disruption buffer (2.0 L) was heated to 60° and placed in an ultra-sonic bath in a fume hood. To the disruption buffer was added dithiolthreitol (2.5 g, Sigma cat #D-0632 or equivalent). The peptide pins were sonicated in this medium for 30 min, washed thoroughly with milliQ waster, suspended in a boiling ethanol bath for 2 min, and air-dried.

Blocking buffer (200 μL) was added to a 96 well disposable polystyrene Elisa plate and the peptide pins suspended in the wells. The peptide pins and plate were incubated for 2 h at room temperature on an oscillating table shaker. The plates and peptide pins were washed with PBS/Tween 20 (four times). To each well was added a 20 μg/ml concentration of cA2 antibody (diluted with blocking buffer, 175 μL/well). TNF competition was done by incubation of TNFα (40 μg/ml) and cA2 (20 μg/ml) in BSA/ovalbumin/BBS for three hours at room temperature. The peptide pins were suspended in the plate and incubated at 4° overnight. The peptide pins and plate were washed with PBS/Tween 20 (four times). To each well was added anti-human goat antibody conjugated to horseradish peroxidase (diluted with blocking buffer to 1/2000, 175 μL/well, Jackson IMMUNORESEARCH Labs). The peptide pins were suspended in the plate, and incubated for 1 h at room temperature on a oscillating table shaker. The plates and peptide pins were washed with PBS/Tween 20 (four times). To each well added freshly prepared substrate solution (150 μL/well), the peptide pins were suspended in the plate and incubated for 1 h at room temperature on an oscillating table shaker. The peptide pins were removed and to each well is added 4N H_2SO_4 (50 μL). The plates were read in a Molecular Devices plate reader (490 nm, subtracting 650

nm as a blank), and the results are shown in Figures 14A and 14B, as described above.

EXAMPLE XIII

Production Mouse Anti-Human TNF mAb

Using TNF Peptide Fragments

Female BALB/c mice, as in Example I above, are injected subcutaneously and intraperitoneally (i.p.) with forty μg of purified E. coli-derived recombinant human TNF (rhTNF) fragments comprising anti-TNF epitopes of at least 5 amino acids located within the non-contiguous sequence 59-80, 87-108 or both residues 59-80 and 87-108 of TNF (of SEQ ID NO:1), as presented above, emulsified with an equal volume of complete Freund's adjuvant (obtained from Difco Laboratories) in 0.4 ml is into a mouse. One week later, a booster injection of 5 μg of these rhTNF fragments in incomplete Freund's adjuvant is given i.p. followed by four consecutive i.p. injections of 10 μg of TNF fragments including anti-TNF epitopes including amino acids from residues 59-80, 87-108 or both 59-80 and 87-108 of hTNFα (of SEQ ID NO:1) without adjuvant. Eight weeks after the last injection, the mouse is boosted i.p. with 10 μg of TNF.

Four days later, the mouse is sacrificed, the spleen is obtained and a spleen cell suspension is prepared. Spleen cells are fused with cells of the nonsecreting hybridoma, Sp2/0 (ATCC CRL1581), at a 4:1 ratio of spleen cells to Sp2/0 cells, in the presence of 0.3 ml of 30% polyethylene glycol, PEG 1450. After incubation at 37°C for 6 hours, the fused cells are distributed in 0.2 ml aliquots into 96-well plates at concentrations of 2 x 10^4 SP2/0 cells per well. Feeder cells, in the form of 5 x 10^4 normal BALB/c spleen cells, are added to each well.

The growth medium used consisted of RPMl-1640 medium, 10% heat-inactivated fetal bovine serum (FBS) (Hyclone), 0.1 mM MEM nonessential amino acids, 1 mM sodium pyruvate, 2mM L-glutamine, 100 U/ml penicillin, 100 μg/ml

streptomycin (GIBCO Laboratories) and, for selection, hypoxanthine-aminopterin-thymidine (HAT) (Boehringer Mannheim). A solid-phase radioimmunoassay (RIA) is employed for screening supernatants for the presence of mAbs specific for rhTNFα fragments including portions of residues 59-80, 87-108 or both 59-80 and 87-108 of hTNFα (of SEQ ID NO:1). This assay is described in Example II, above. The background binding in this assay is about 500 cpm. A supernatant is considered positive if it yielded binding of 2000 cpm or higher.

Of the supernatants screened, one or more positive supernatants are routinely identified by RIA. Of these positive supernatants, the highest binding (as shown by the higher cpm values) are subcloned at limiting dilution on mouse feeder cells. Upon further analysis of the supernatants in neutralization assays, routinely one or more antibodies are found to have potent inhibiting and/or neutralizing activity. These positive and inhibiting and/or neutralizing hybridoma lines are then selected and maintained in RPMl-1640 medium with 10% FBS (GIBCO), 0.1 mM nonessential amino acids, 1 mM sodium pyruvate, 2 mM L-glutamine, 100 U/ml penicillin and 100 μg/ml streptomycin.

EXAMPLE XIV

Production of Murine and chimeric antibodies, fragments and regions from TNF Peptides

Murine and chimeric antibodies, fragments and regions are obtained by construction of chimeric expression vectors encoding the mouse variable region of antibodies obtained in Example XIV and human constant regions, as presented in Examples IV-IX above.

The resulting chimeric A2 antibody is purified from tissue culture supernatant by Protein A-Sepharose chromatography. The supernatant is adjusted to 0.1M Tris, 0.002M EDTA, pH 8.0 and loaded on a Protein A-Sepharose column equilibrated in the same buffer. The IgG is then eluted with 0.1M citrate, pH 3.5, neutralized with 1M Tris,

and dialyzed into phosphate buffered saline (PBS).

The purified murine and chimeric antibodies, fragments and regions are evaluated for its binding and inhibiting and/or neutralizing activity.

EXAMPLE XV

In Vitro Activity and Neutralization Efficacy of a Chimeric Anti-TNF Antibody

Both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, are determined to have potent TNF-inhibiting and/or neutralizing activity, as shown for example, in the TNF cytotoxicity assay described above, expressed as the 50% Inhibitory Dose (ID50).

In this same experimental system, three other murine anti-TNFα antibodies (termed TNF-1, TNF-2 and TNF-3) of comparable binding affinity to TNF are found to have ID50 values of 1-2 orders of magnitude greater, and thus have significantly less potent in neutralization, than both the murine and chimeric anti-TNFα antibodies of the present invention.

The ability of both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, to inhibit or neutralize human TNFα bioactivity *in vitro* is tested using the bioassay system described above. Cultured cells producing the murine or chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, are incubated with 40 pg/ml natural (Genzyme, Boston, MA) or recombinant (Suntory, Osaka, Japan) human TNF with or without antibody overnight as above, and cell death is measured by vital staining. As expected, both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, inhibited or neutralized both natural and rhTNF in a dose-dependent manner in the cytotoxicity assay. Such inhibiting and/or neutralizing potency, at antibody levels below 1 μg/ml, can easily be

attained in the blood of a subject to whom the antibody is administered. Accordingly, such highly potent inhibiting and/or neutralizing anti-TNF antibodies, in particular the chimeric antibody, are preferred for therapeutic use in TNFα-mediated pathologies or conditions.

The ability of cA2 to inhibit or neutralize TNF-induced IL-6 secretion is evaluated using cultured human diploid FS-4 fibroblasts. The results are expected to show that both murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, are effective in blocking IL-6 secretion in cells that had been incubated overnight with TNF. TNF-induced IL-6 secretion is not inhibited in the absence of a mAb or in the presence of a control mAb specific for an irrelevant antigen.

The ability of TNF to activate procoagulant and adhesion molecule activities of endothelial cells (EC) is thought to be an important component of pathology pathophysiology. In particular, this can be associated with the vascular damage, disseminated intravascular coagulation, and severe hypotension that is associated with the sepsis syndrome. Therefore, the ability of both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, to block TNF-induced activation of cultured human umbilical vein endothelial cells (HUVEC) is evaluated. TNF stimulation of procoagulant activity is determined by exposing intact cultured HUVEC cells to TNF (with or without antibody) for 4 hours and analyzing a cell lysate in a human plasma clotting assay. The results are expected to show the expected upregulation by TNF of HUVEC procoagulant activity (reflected by a decreased clotting time). Both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, are expected to effectively inhibit or neutralize this TNF activity in a dose-dependent manner.

In addition to stimulating procoagulant activity,

TNF also induces surface expression of endothelial cell adhesion molecules such as ELAM-1 and ICAM-1. The ability of both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, are expected to inhibit or neutralize this activity of TNF is measured using an ELAM-1 specific detection radioimmunoassay. Cultured HUVEC are stimulated with 250 ng/ml rhTNF (Dainippon, Osaka, Japan) with or without antibody at 37°C overnight in a 96-well plate format. Surface expression of ELAM-1 is determined by sequential addition of a mouse anti-human ELAM-1 mAb and ^{125}I-labelled rabbit anti-mouse immunoglobulin second antibody directly to culture plates at 4°C.

TNF is expected to induce the expression of ELAM-1 on the surface of cultured HUVEC cells, and this activity is again expected to be effectively blocked in a dose-related manner by both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV.

Finally, TNF is known to stimulate mitogenic activity in cultured fibroblasts. Both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, are expected to inhibit or neutralize TNF-induced mitogenesis of human diploid FS-4 fibroblasts cultures, confirming the potent inhibiting and/or neutralizing capability of both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV against a broad spectrum of *in vitro* TNF biological activities.

EXAMPLE XVI

In Vivo Activity and Efficacy of cA2 Antibody

Evidence that the potent *in vitro* inhibiting and/or neutralizing capability of cA2 is manifest *in vivo* was obtained. Earlier animal studies showed that administration of TNF to experimental animals mimics the pathology state obtained with either Gram-negative bacterial infection or

direct endotoxin administration (Tracey, et al., 1986. *infra*; Tracey, et al., 1987, *infra*; Lehmann, et al., *infra*).

An *in vivo* model wherein lethal doses of human TNF are administered to galactosamine-sensitized mice (Lehmann, V. et al., *infra*) is substantially modified for testing the capability of both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV above, to inhibit or neutralize TNF *in vivo*. An i.p. challenge with 5 μg (0.25 mg/kg) of rhTNF resulted in 80-90 percent mortality in untreated control animals and in animals treated i.v. 15-30 minutes later with either saline or 2 mg/kg control antibody (a chimeric IgG1 derived from murine 7E3 anti-platelet mAb). In contrast, treatment with both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, is expected to reduce mortality to 0-30 percent with 0.4 mg/kg of antibody, and to 0-10 percent with 20 mg/kgs. These expected results indicate that both the murine and chimeric anti-TNFα antibodies of the present invention, as obtained according to Examples XIV and XV, are capable of inhibiting and/or neutralizing the biological activity of TNF in vivo as well as *in vitro*.

TABLE 4

PREVENTION OF HUMAN TNF-INDUCED LETHALITY BY CHIMERIC A2

	Outcome (Survivors/Total)	
Antibody	Experiment #1	Experiment #2
None	1/10	N.D.
Control Ab, 2 mg/kg	2/10	1/10
cA2 (2 mg/kg) (p=0.0001)	9/10 (p=0.0055)	10/10
cA2 (0.4 mg/kg) (p=0.0001)	7/10 (p=0.07)	10/10

Female C3H/HeN mice were administered 5 μg rhTNF (Dainippon, Osaka, Japan)

+ 18 mg galactosamine i.p. and antibody was administered 15-30 minutes later i.v. Deaths were recorded 48 h post-challenge. Control MAb = chimeric mouse/human IgG1 anti-platelet MAb (7E3). N.D. = not done. p values refer to comparison with the control Ab.

EXAMPLE XVII

cA2 MAb Safety in Chimpanzees

The epitope specificity of A2 can be for an epitope which predominates in humans and chimpanzees. Therefore, the chimpanzee was chosen as a relevant mammalian species to determine the toxicological potential and provide safety information for cA2. Chimpanzees were dosed at levels of 15 mg/kg for four to five consecutive days and 30 mg/kg once or for three consecutive days. No adverse clinical signs, and no changes considered to be cA2 treatment related were observed in the monitored parameters including routine hematology and blood chemistry. Thus, doses of up to 30 mg/kg for three consecutive days were well tolerated in chimpanzees.

EXAMPLE XVIII

Clinical Activity and Efficacy of cA2 Antibody

Chimeric IgG1 anti-human TNF MAb cA2 was administered to healthy male human volunteers as patients. One hour after receiving 4 ng/kg of an NIH reference endotoxin, the volunteers were administered either saline, as a control, or 0.01, 0.10 or 10 mg/kg of cA2 in a pharmaceutically acceptable form. TNF levels in serum were measured over time and were found to show a dose dependent decrease in peak TNF levels with no TNF being detected in volunteers receiving a 10 mg/kg dose of cA2. Accordingly, therapy with an anti-TNF antibody of the present invention is expected to inhibit TNF-mediated effects in humans.

Patients receiving endotoxin developed pronounced leukopenia thought to be due to margination of white blood cells. As the white blood cells become activated, they can attach to endothelial receptors with resultant endothelial damage. At doses of 1.0 to 10.0 mg/kg, this leukopenia is

prevented, whereas, at 0.01 and 0.1 mg/kg dosages, a drop in white cell count was observed. The drop was most pronounced among the polymorph cell line. In all patients there was a subsequent leukocytosis, which was unchanged by treatment with anti-TNF anti-body cA2. This blocking effect on white blood cell margination is expected to represent a protective effect against the endothelial damage associated with TNF. It is expected in the art that this TNF-related endothelial damage plays a significant role in the morbidity and mortality associated with sepsis, and it is therefore expected that the anti-TNF antibodies of the present invention will provide a protective effect against these damaging effects, as presented herein.

EXAMPLE XIX

Treatment of Sepsis in Humans Using a Chimeric Anti-TNF Antibody

The chimeric anti-TNF MAb cA2 has been used in two phase I/II studies. In a phase I/II study in septic patients, 20 patients with the sepsis syndrome received a single dose of either 0.1, 1.0, 5.0 or 10 milligrams of cA2 per kilogram bodyweight. Another 60 patients received 100 milligrams of HA-1A, a human anti-lipid A Mab currently under evaluation for gram negative sepsis, followed with either placebo or 1.0, 5.0, or 10 milligrams cA2 per kilogram bodyweight. The cA2 was administered as a single, intravenous infusion over a 60 minute period. Clinical assessment, vital signs, and laboratory parameters were measured before, during and periodically for 28 days after the infusion. In this study, cA2 was well tolerated. No adverse events were reported as "probably" or "definitely" related to cA2. All deaths were reported as "definitely not" related to cA2.

Accordingly, human treatment of rheumatoid arthritis in human patients was expected, and found, to provide a suitable treatment, as described herein.

EXAMPLE XX:

CLINICAL TREATMENT OF RHEUMATOID ARTHRITIS BY A ANTI-TNF ANTIBODY OR PEPTIDE OF THE PRESENT INVENTION

A Phase I open label study was conducted for methods and compositions of the present invention using a chimeric anti-TNF MAb for the treatment of patients with severe refractory rheumatoid arthritis. Nine patients were enrolled in the study. The first five patients were treated with chimeric anti-TNF antibody (cA2), 10 mg/kg as a single dose infused over a period of two hours. These patients were subsequently retreated with a second infusion of 10 mg/kg on day 14 of the study. The second group of five patients received an infusion of 5 mg/kg on the first day of the study. They were then treated with additional infusions of 5

mg/kg on days 5, 9, and 13. Four of the planned five patients in this second group have been treated to date.

Preparation, Administration, and Storage of Test Material

The chimeric monoclonal anti-TNF antibody was supplied in single-use glass vials containing 20 mL with 100 mg of anti-TNF (5 mg/mL). The anti-TNF antibody was stored at 2-8°C. Prior to infusion, the antibody was withdrawn from the vials and filtered through a low-protein-binding 0.22 μm filter. This filtered antibody was then diluted to a final volume of 300 mL with normal saline. The 300 mL antibody preparation was then infused via an in-line filter over a period of not less than two hours.

Prior to each repeat infusion of study medication a test dose of 0.1 mL of the infusion was diluted in 10 mL of normal saline and administered by slow IV push over 5 minutes. The patient was observed for 15 minutes for signs or symptoms of an immediate hypersensitivity reaction. If no reaction was observed in this time period, the full dose was administered as described above.

Administration Protocol

Group 1 (patients 1-5): a total of 2 infusions, on day 1 and day 15 of the trial; dosage 10 mg/kg on each occasion;

Group 2 (patients 6-9): a total of 4 infusions, on days 1, 5, 9 and 13 of the trial; dosage 5 mg/kg on each occasion.

All infusions were administered iv over 2 hours in a total volume of cA2 + saline of 300 ml. Infusions subsequent to the first in any patient were preceded by a small test dose administered as an iv push. All patients had at least three years of disease activity with rheumatoid arthritis. The patients ranged in age from 23 to 63. All patients had failed therapy with at least three different DMARD (Disease Modifying Anti-Rheumatic Drug). Six of the nine patients had serum rheumatoid factors, and all nine patients had erosions present on X-rays.

Clinical Monitoring

Patients were monitored during and for 24 hours after infusions for hemodynamic change, fever or other adverse events. Clinical and laboratory monitoring for possible adverse events was undertaken on each follow-up assessment day. Clinical response parameters were performed at the time-points as specified in the flow chart present in Table 9. These evaluations were performed prior to receiving any infusions.

Clinical response studies will be comprised of the following parameters:

1. Number of tender joints and assessment of pain/tenderness

The following scoring will be used:

0 = No pain/tenderness

1 = Mild pain. The patient says it is tender upon questioning.

2 = Moderate pain. The patient says it is tender and winces.

3 = Severe pain. The patient says it is tender and winces and withdraws.

2. Number of swollen joints

Both tenderness and swelling will be evaluated for each joint separately. MCP's, PIP's etc. will not be considered as one joint for the evaluation.

3. Duration of morning stiffness (in minutes)

4. Grip strength

5. Visual analog pain scale (0-10 cm)

6. Patients and blinded evaluators will be asked to assess the clinical response to the drug. Clinical response will be assessed using a subjective scoring system as follows:

5 = Excellent response (best possible anticipated response)

4 = Good response (less than best possible anticipated response)

3 = Fair response (definite improvement but could be better)

2 = No response (no effect)

1 = Worsening (disease worse)

Measurement of index of disease activity is scored according to the following Table 5.

Table 5. Clinical characteristics of patients 1-5

Patient Number	Age/Sex	Disease Duration (years)	Rheumat. Factor	Erosions/ Nodules	Previous Treatment (DMARDs only)	Concomitant Anti-rheumatic Therapy
01	48/F	7	+ve	+ve/+ve	*Sal,DP,Myo,Aur, MTX,Aza,Chl.	**Pred 5 mg
02	63/F	7	-ve	+ve/-ve	Sal,Myo,DP.	Para 1-2g
03	59/M	3	+ve	+ve/-ve	Aur,Chl,Myo, MTX,Sal.	Pred 10 mg, Ind 225 mg
04	56/M	10	+ve	+ve/-ve	Myo,DP,Aza,Sal.	Pred 12.5 mg, Ibu 2g, Para 1-2g
05	28/F	3	+ve	+ve/-ve	Myo,Sal,DP,Aza.	Pred 8mg, Para 1-2g, Cod 16 mg

*Sal = Sulphasalazine; DP = D-penicillamine; Myo = Myocrisin; Aur = auranofin; MTX = methotrexate; Aza = azathioprine; Chl = hydroxychloroquine. **Pred = prednisolone (dosage/day); Para = paracetamol; Ind = indomethacin; Ibu-ibuprofen; Cod = codeine phosphate.

Table 6. Clinical characteristics of patients 6-9

Patient Number	Age/Sex	Disease Duration (years)	Rheumat. Factor	Erosions/ Nodules	Previous Treatment (DMARDs only)	Concomitant Anti-rheumatic Therapy
06	40/M	3	+ve	+ve/-ve	*Sal,Chl,Aur.	**Nap 1 g
07	54/F	7	-ve	+ve/-ve	DP,Myo,Sal,Aza, MTX.	Para 1-2g, Cod 16-32 mg.
08	23/F	11	+ve	+ve/-ve	Chl,Myo,Sal, MTX, Aza.	Pred 7.5 mg, Dicl 100 mg, Para 1-2g, Dext 100-200 mg.
09	51/F	15	-ve	+ve/+ve	Myo,Chl,DP, MTX.	Pred 7.5 mg, Dicl 125 mg, Para 1-3g.

*Sal = Sulphasalazine; Chl = chloroquine or hydroxychloroquine; Aur = auranofin; DP = D-penicillamine; Myo = Myocrisin; Aza = azathioprine; MTX = methotrexate. **Nap = naprosyn (dosage/day); Para = paracetamol; Cod = codeine phosphate; Pred = prednisolone; Dicl = diclofenac; Dext = dextropropoxyphene.

Table 7. Disease activity at entry for patients 1-5

Patient IDA Number	Morning Stiffness (mins)	Pain (0-10 cm on VAS)	Number Swollen Joints (0-28)	Ritchie Articular Index (0-69)	Grip Strength L/R (mm/Hg; max 300)		ESR (mm/hr normal ranges: F<15; M<10)	CRP (mg/l; normal range: <10)	(range: 1-4)
01	60	3.9	19	30	108/107	35	5	2.67	
02	20	2.7	25	31	67/66	18	14	2.0	
03	90	4.9	14	16	230/238	48	44	2.5	
04	30	6.9	17	12	204/223	24	35	2.33	
05	90	5.7	28	41	52/89	87	107	3.0	

Table 8. Disease activity at entry for patients 6-9

Patient IDA Number	Morning Stiffness (mins)	Pain (0-10 cm on VAS)	Number Swollen Joints (0-28)	Ritchie Articular Index (0-69)	Grip Strength L/R (mm/Hg; max 300)		ESR (mm/hr normal ranges: F<15; M<10)	CRP (mg/l; normal range: <10)	(range: 1-4)
06	120	5.0	3	4	260/280	23	33	2.33	
07	105	7.4	27	31	59/80	25	10	2.83	
08	270	9.3	17	37	73/125	35	31	3.17	
09	180	4.5	20	26	53/75	15	33	2.5	

All patients have tolerated the infusions of chimeric anti-CD4 and no serious adverse reactions have been observed. Specifically, no episodes of hemodynamic instability, fevers, or allergic reactions were observed in association with the infusions. Patients have not experienced any infections.

Although this is a non-blinded study, all patients experienced improvement in their clinical assessments of disease status, as well in biochemical parameters of inflammation measured in their serum.

Clinical assessments, including the duration of early morning stiffness; the assessment of pain on a visual analogue scale; total count of swollen joints; Ritchie articular index (a scaled score which assesses the total number of tender joints and the degree of joint tenderness);

and Index of Disease Activity (a scaled score which incorporates several clinical and laboratory parameters), showed impressive improvements compared to controls. These improvements were typically in the range of an 80% drop from the baseline score; a degree of improvement which is well beyond the amount of improvement that can be attributed to placebo response. In addition, the duration of these improvements was for six to eight weeks in most cases, a duration of response far longer than would be anticipated from a placebo.

The improvements in clinical assessments were corroborated by improvements in biochemical inflammatory parameters measured in serum. The patients showed rapid drops of serum C-reactive protein, usually in the range of 80% from the baseline. Reductions in the erythrocyte sedimentation rate, usually in the range of 40%, were also observed. Circulating soluble TNF receptors were also decreased following therapy. The durations of the biochemical responses were similar to the duration of the clinical responses.

Preliminary assessment of immune responses to the chimeric anti-TNF antibody has shown no antibody response in the first four patients.

In summary, the preliminary evaluation of the results of this Phase I trial indicate that treatment of patients with advanced rheumatoid arthritis with anti-TNF MAb of the present invention is well tolerated and anti-TNF treatment is associated with rapid and marked improvement in clinical parameters of disease activity, including early morning stiffness, pain, and a number of tender and swollen joints; and is accompanied by improvement of biochemical parameters of inflammation.

Although this was an open label study, the magnitude of the clinical improvements is well beyond the degree of improvement that would be anticipated from a placebo response, such that the present invention is shown to have significant clinical efficacy for treating rheumatoid

arthritis.

Table 9A

Flowchart for CHIMERIC ANTI-TNF STUDY C0168TRA

Group I (10 mg/kg at day 1 and day 14)

	Pre Scr	Screening	Wk d1	0 d 2	Wk 1	Wk 2 d 14	Wk 3	Wk 4	Wk 6	Wk 8	
Consent	x										
Demography		x									
Physical Examination		x								x	
Pregnancy Test		x									
Weight		x	x			x				x	
Vital Signs		x	x*	x	x	x*	x	x	x	x	
Anti-TNF Infusion			x			x					
Labs, see Chart		x	x'	x	x	x'	x	x	x	x	
Clinical (Safety)				x	x	x'	x	x	x	x	
Clinical (Response)		x	x'		x	x'	x	x	x	x	

Synovial biopsy		x			x7	-					
Response evaluation										x	

	Screening	Wk d1	0 d2	Wk 1	Wk 2 d14	Wk 3	Wk 4	Wk 6	Wk 8	
Hematology + ESR	x	x'		x	x'	x	x	x	x	
Biochemistry	x	x'		x	x'	x	x	x	x	
Urinalysis		x'		x	x'	x	x	x	x	
CRP + RF		x'		x	x'	x	x	x	x	
Serum Cytokines		x'		x	x'	x	x	x	x	
PBL		x	x	x						
Pharmacokinetics		x#	x#		x$					
HACA response		x'		x	x'	x	x	x	x	x

x* = Vital signs will be obtained prior to infusion, every 30 minutes during the infusion and every 30 minutes for 2 hours after the infusion.

x' = Needs to be done prior to the infusion.

x# = Serum samples will be obtained prior to the infusion and at 1, 2, 4, 8, 12, and 24 hours after the end of the infusion.

x$ = Serum samples will be obtained to the infusion and at 2 hours

after the end of the infusion.

Table 9B

Flowchart for CHIMERIC ANTI-TNF STUDY C0168TRA
Group II2 (mg/kg every 4 days, 4 times total)

	Pre Scr	**Screening**	d 1	wk d 2	0 d 5	+ d 9	1 d 13	wk 2	wk 3	wk 4	wk 6	wk 8	
Consent	x												
Demography		x											
Physical exam		x										x	
Pregnancy test		x											
Weight		x	x		x	x	x					x	
Vital signs		x	x *	x	x *	x *	x *	x	x	x	x	x	
Anti-TNF Infusion			x		x	x	x						
Labs, see chart		x	x '	x	x '	x '	x '	x	x	x	x	x	x
Clinical Safety				x	x '	x '	x '	x	x	x	x	x	
Clinical Response		x	x '			x '		x	x	x	x	x	
Synovial Biopsy		x					x 7						
Response Evaluation												x	

	screening	d1	wk d2	0 d5	+ d9	1 d13	wk 2	wk 3	wk 4	wk 6	wk 8
Hematology + ESR	x	x'			x'		x	x	x	x	x
Biochemistry	x	x'			x'		x	x	x	x	x
Urinalysis		x'			x'		x	x	x	x	x
CRP + RF		x'			x'		x	x	x	x	x
Cytokines		x'			x'		x	x	x	x	x
PBL		x	x		x				x		
Pharmaco-kinetics		x#	x#	x$	x$	x$					
HACA Response		x'			x'		x	x	x	x	x

x* = Vital signs will be obtained prior to infusion, every 30 minutes during the infusion and every 30 minutes for 2 hours after infusion.

x' = Needs to be done prior to the infusion.

x# = Serum samples will be obtained to the infusion and at 1, 2, 4, 8, 12, and 24 hours after the end of the infusion.

x$ = Serum samples will be obtained prior to the infusion and at 2 hours after the end of the infusion.

Table 10
Measurement of the index of disease activity (DA)
Variables of Disease Activity

IDA score	Morning Stiffness (min)	Pain (VAS, cm) *	Grip Strength (mmHg)	Ritchie Articular Index	Hemoglobin (g/dl) Male	Hemoglobin (g/dl) Female	ESR
1	<10	0-2.4	>200	0	>14.1	>11.7	0-20
2	10-30	2.5-4.4	50-200	1-7	13-14	10.8-11.6	21-45
3	31-120	4.5-6.4	30-49	8-17	10-12.9	8.4-10.7	46-80
4	>120	6.5-10	<30	>18	<9.9	<8.3	>81

*Pain was measured on a visual analog scale (VAS) 0-10 cm.

Conclusions (1)

Safety of anti-TNF in RA

Anti-TNF was safe and very well tolerated:
- no hemodynamic, febrile or allergic episodes;
- no infections;
- no clinical adverse events;
- a single laboratory adverse event only, probably unrelated to anti-TNF.

Conclusions (2)

Efficacy of anti-TNF in RA
Anti-TNF therapy resulted in:

- rapid and marked improvements in EMS, pain and articular index in most patients;

- slower but marked improvement in swollen joint score, maximal by 3-4 weeks;

- rapid and impressive falls in serum CRP, and a slower fall in ESR;

- normalization of CRP and ESR in some patients;

- rapid falls in serum C4d (a complement breakdown product) and IL-6 in patients where these indices were elevated at entry.

Duration of clinical improvements variable, with rebound in some patients at 6-8 weeks.

Accordingly, the present invention has been shown to have clinical efficacy in human patients for treating TNF involved pathologies using TNF MAbs of the present invention, such as for treating rheumatoid arthritis. Additionally, the

human clinical use of TNF antibodies of the present invention in humans is also shown to correlate with *in vitro* data and *in vivo* animal data for the use of anti-TNF antibodies of the present invention for treating TNF-related pathologies.

EXAMPLE XXI:

TREATMENT OF CROHN'S DISEASE IN HUMANS USING ANTI-TNFα ANTIBODIES.

Case history SB.

This 16 year old patient has a history of Crohn's disease since age 12. She was suffering from diarrhoea, rectal blood loss, abdominal pain, fever and weight loss. She showed perianal lesions, severe colitis and irregularity of the terminal ileum. She was treated with prednisolone (systemic and local) and pentasa. This resulted in remission of the disease, but she experienced extensive side effects of the treatment. She experienced severe exacerbations at age 12 and 12 yrs, 5 months, (Immuran™ added), 12 yrs, 9 months, 13 yrs, 5 months, and 14 yrs, 10 months. She experienced severe side effects (growth retardation, morbus Cushing, anemia, muscle weakness, delayed puberty, not able to visit school).

At 15 yrs, 11 months, she was diagnosed with a mass in the right lower quadrant. She had a stool frequency of 28 time per week (with as much as 10 times per day unproductive attempts). The Crohn's index wad 311, the pediatric score 77.5. The sedimentation rate was elevated. Albumen and hemoglobin reduced. Before the first treatment the score was 291 and pediatric score was 60, and she would possibly have to loose her colon. She was infused on compassionate grounds with 10 mg/kg cA2, without any side effects noticed. One week after treatment her sedimentation rate was reduced from 66 to 32 mm. The Crohn's index was 163 and pediatric score 30. She was reported to feel much better and the frequency of the stools was reduced greatly. Thee was apparently no more diarrhoea, but normal faeces. On October 15th, before the second infusion she had gained weight, had a

sedimentation rate of 20 mm, an albumen of 46 h/l, Crohn's index 105, pediatric score 15. There seemed to be improvement on video endoscopy. A second infusion was performed at 16 yrs.

The patient was greatly improved after the second infusion. A endoscopy showed only 3 active ulcers and scar tissue.

This is in contrast with her colon on admission when the thought was that her colon should be removed. This case history shows a dramatic improvement of severe Crohn's disease upon treatment with cA2 anti-TNF antibody.

Table 11:

CASE HISTORY SB

11y, 8m:	physical examination:	Diarrhoea, rectal blood loss, abdominal pain, fever (40%) weight loss perianal lesions
	sigmoidoscopy:	severe colitis, probably M. Crohn
	enterolysis:	irregularity terminal ileum
	Therapy:	prednisolone 10 mg 3 dd. Pentasa 250 mg 3 dd. enema (40 mg prednisone, 2g 5 ASA) ml 1 dd.
	Result:	remission, however: extensive side effects of prednisone and stunting growth
	Action:	prednisone
11y, 11m	exacerbation	same clinical picture as 11 y, 8 m
	sigmoidoscopy:	recurrence of colitis (grade IV) in last 60 cm and anus.
	Therapy:	prednisolone 40 mg 1 dd Pentasa 500 mg 3 dd enema 1 dd
	Result:	better
12y, 5m:	severe exacerbation; despite intensive treatment	
	sigmoidoscopy:	extensive perianal and sigmoidal lesions; active disease
	Therapy:	continued + Immuran(TM) 25 mg 1 dd
	Result:	slight improvement however still growth retardation, cushing, anaemia, muscle weakness.

Action: prednisone

12y, 9m: exacerbation
sigmoidoscopy: extensive (active) colitis, polyps
Action: prednisone: 30 mg 1 dd, Immuran(TM) 50 mg 1 dd, Pentasa 500 mg 3 dd, enema 2 dd
Result: still needs enema's with prednisone and oral prednisone. delayed puberty, stunting growth

14y, 10m: severe exacerbation, weight loss, abdominal pain, fever.
ileoscopy: active colitis (grade IV), perianal lesions. Terminal ileum normal.
Result: No remission still fever, poor appetite, weight loss, diarrhea, not able to visit school

Important Findings:
14y, 11m: 151.9 cm; 34 kg
T=38°C, Abdominal mass in right lower quadrant
stool frequency 28 per week
(however goes 10-15 times a day but most often without success)
ESR 55 mm; Hb 6.2 mmol/1
Ht 0, 29 1/1; alb. 38.4 g/l
Crohn's Dis. Act. Index: 311
Pediatric score: 77.5

14y, 11.2m: 151,8 cm: 34.6 kg
(before 1st infusion)
Crohn's Dis
Act Index: 291
Pediatric score: 60

14y, 11.4m: 151,8 cm: 34.6 kg
ESR 32 mm; Hb 5.7 mmol/1
Crohn's Dis
Act Index: 163
pediatric score: 30

15y, 0m 152,1 cm: 34.8 kg
(before 2nd infusion Feels like she has never
felt before. Parents also very enthusiastic
ESR 30 mm: Hb 6, 3 mol/1
Ht 0,32 11; Alb 46 g/l
Crohn Dis
Act Index: 105
Pediatric Score: 15
Videoendoscopy: Improvement

No problems or side effects observed during and following infusion.

Accordingly, anti-TNF antibodies according to the present invention, as exemplified by cA2, are shown to provide successful treatment of TNF related pathologies, as exemplified by Crohn's disease, in human patients with no or little side effects.

EXAMPLE XXII: TREATMENT OF ARTHRITIS IN HUMANS USING CHIMERIC IMMUNOGLOBULIN CHAIN OF THE PRESENT INVENTION

Patient Selection

Twenty patients were recruited, each of whom fulfilled the revised American Rheumatism Association criteria for the diagnosis of RA (Arnett et al., *Arthritis Rheum.* 31:315-324 (1988). The clinical characteristics of the patients are shown in Table 12. The study group comprised 15 females and 5 males, with a median age of 51 years (range 23-72), a median disease duration of 10.5 years (range 3-20) and a history of failed therapy with standard disease - modifying anti-rheumatic drugs (DMARDs; median number of failed DMARDs: 4, range 2-7). Seventeen were seropositive at entry or had been seropositive at some stage of their disease, all had erosions on X-Rays of hands or feet, and 3 had rheumatoid nodules. All patients had active disease at trial entry, as defined by an Index of Disease Activity (IDA; Mallya et al., *Rheumatol. Rehab.* 20:14-17 (1981) of at least 1.75, together with at least 3 swollen joints, and were classed as anatomical and functional activity stage 2 or 3 (Steinbrocker et al., *JAMA* 140:659-662 (1949). The pooled data for each of the clinical and laboratory indices of disease activity at the time of screening for the trial (up to 4 weeks prior to trial entry), and on the day of trial entry itself (week 0), are shown in Tables 13 and 14.

Table 12. Demographic features of 20 patients with refractory rheumatoid arthritis.

Patient	Age/Sex	Disease Duration (years)	Previous DMARDs	Concomitant Therapy
1	48/F	7	SSZ,DP,GST,AU RMTX,AZA,HCQ	Pred 5 mg
2	63/F	7	SSZ,GST,DP	Para 1-2g
3	59/M	3	AUR,HCQ,GST, MTX,SSZ	Pred 10 mg, Indo 225 mg
4	56/M	10	GST,DP,AZA,SS Z	Pred 12.5 mg, Ibu 2 g, Para 1-2 g
5	28/F	3	GST,SSZ,DP,AZ A	Pred 8 mg, Para 1-2 g, Cod 16 mg
6	40/M	3	SSZ,HCQ,AUR	Nap 1 g
7	54/F	7	DP,GST,SSZ,AZ A MTX	Para 1-2 g, Cod 16-32 mg
8	23/F	11	HCQ,GST,SSZ, MTX AZA	Pred 7.5 mg, Dicl 100 mg, Para 1-2g, Dex 100-200 mg
9	51/F	10	GST,HCQ,DP,MT X	Pred 7.5 mg, Dicl 125 mg, Para 1-3g
10	47/F	12	SSZ,CYC,MTX	Ben 4 g
11	34/F	10	DP,SSZ,MTX	Pred 10 mg, Para 1.5 g, Cod 30-90 mg
12	57/F	12	GST,MTX,DP,AU R	Asp 1.2 g
13	51/F	7	SSZ,AZA	Para 1-4 g
14	72/M	11	GST,DP,AZA,MT X	Pred 5 mg, Para 1-4 g, Cod 16-64 mg
15	51/F	17	HCQ,DP,SSZ,MT X	Asp 0.3 g
16	62/F	16	GST,DP,SSZ,MT X AZA	Para 1-4 g, Cod 16-64 mg

17	56/F	11	SSZ,DP,GST,MTX HCQ,AZA	Pred 7.5 mg, Eto 600 mg, para 1-2g, Dext 100-200 mg
18	48/F	14	GST,MTX,DP,SSZAUR,AZA	Pred 7.5 mg, Indo 100 mg, Para 1-3 g
19	42/F	3	SSZ,MTX	Fen 450 mg, Ben 6 g, Cod 30 mg
20	47/M	20	GST,DP,SSZ,AZA	Pred 10 mg, Para 1-3 g

*DMARDs=disease - modifying anti-rheumatic drugs
SSZ=sulphasalazine; DP=D-penicillamine; GST=gold sodium thiomalate; AUR=auranofin; MTX=methotrexate; AZA=azathioprine; HCQ=(hydroxy)chloroquine; CYC=cyclophosphamide. Pred=prednisolone (dose/day); Para=paracetamol; Indo=Indomethacin; Ibu=ibuprofen; Cod=codeine phosphate; Nap=naprosyn; Dicl=diclofenac; Dext=dextropropoxyphene; Ben=benorylate; Asp=aspirin; eto=etodolac; Fen=fenbufen.

Table 13 Changes in clinical assessments following treatment of rheumatoid arthritis patients with cA2.

Week of Trial	Morning Stiffness	Pain Score (0-10)	Ritchie Index (0-69)	Swollen Joints (0-28)	Grip Strength (L) (0-300)	Grip Strength (R) (0-300)	IDA (1-4)	Patient Assess - ment (grades improved 0-3)
	min	cm		number	mm Hg	mm Hg		
Screen	135(0-600)	7.4(4-9.7)	23(4-51)	16(4-28)	84(45-300)	96(57-300)	3(2.3-3.3)	NA
p value 0	180(20-600)	7.1(2.7-9.7)	28(4-52)	18(3-27)	77(52-295)	92(50-293)	3(2-3.5)	NA
p value 1	20(0-180) <0.001	2.6(0.6-7.8) <0.001	13(2-28) <0.001; <0.002	13.5(1-25) >0.05	122(66-300) >0.05	133(57-300) >0.05	2(1.5-3.3) <0.001	1(1-3) NA
p value 2	15(0-150) <0.001	3.0(0.3-6.4) <0.001	13(1-28) <0.001	11.5(1-22) <0.003; <0.02	139(75-300) <0.03; >0.05	143(59-300) >0.05	2(1.5-3.2) <0.001	1.5(1-3) NA
p value 3	5(0-150) <0.001	2.2(0.2-7.4) <0.001	8(0-22) <0.001	6(1-19) <0.001; <0.002	113(51-300) >0.05	142(65-300) >0.05	2(1.2-3.2) <0.001	2(1-2) NA
p value 4	15(0-90) <0.001	1.9(0.1-5.6) <0.001	10(0-17) <0.001	6(0-21) <0.001; <0.002	124(79-300) <0.02; >0.05	148(64-300) <0.03; >0.05	1.8(1.3-2.7) <0.001	2(1-2) NA
p value 6	5(0-90) <0.001	1.9(0.1-6.2) <0.001	6(0-18) <0.001	5(1-14) <0.001	119(68-300) <0.04; >0.05	153(62-300) <0.05; >0.05	1.7(1.3-2.8) <0.001	2(1-2) NA
p value 8	15(0-60) <0.001	2.1(0.2-7.7) <0.001	8(1-28) <0.001	7(1-18) <0.001	117(69-300) <0.03; >0.05	167(53-300) <0.03; >0.05	1.8(1.5-2.8) <0.001	2(1-3) NA

Datas are expressed as the median (range) of values from 20 patients; data from patient 15 were not included after week 2 (dropout); P values show significance by Mann-Whitney test compared with week 0 values; adjusted for multiple statistical comparisons. IDA = Index of disease activity; NA = not applicable.

Table 14. Changes in laboratory measures following treatment of rheumatoid arthritis patients with cA2.

Week of Trial	Hgb g/liter	WBC x10/liter	Platelet Count x10/liter	ESR mm/hour	CRP mg/liter	SAA mg/ml	RF Inverse titer

Screen	117(98-146)	7.9(3.9-15.2)	352(274-631)	59(18-87)	42(9-107)	ND	ND
p value 0	113(97-144)	9.0(4.9-15.7)	341(228-710)	55(15-94)	39.5(5-107)	245(18-1900)	2,560(160-10,240)
p value 1	114(96-145) >0.05	8.5(3.6-13.6) >0.05	351(223-589) >0.05	26(13-100) >0.05	5(0-50) <0.001	58(0-330) <0.001; <0.003	ND
p value 2	112(95-144) >0.05	8.2(4.3-12.7) >0.05	296(158-535) <0.04; >0.05	27(10-90) <0.02; >0.05	5.5(0-80) <0.001; <0.003	80(11-900 <0.02; <0.04	ND
p value 3	110(89-151) >0.05	9.0(3.7-14.4) >0;05	289(190-546) <0.03; >0.05	27(12-86) <0.04; >0.05	7(0-78) <0.001; <0.002	ND	ND
p value 4	112(91-148) >0.05	8.2(4.7-13.9) >0.05	314(186-565) >0.05	23(10-87) <0.04; >0.05	10(0-91) <0.004; <0.02	ND	ND
p value 6	116(91-159 >0.05	9.1(2.9-13.9) >0.05	339(207-589) >0.05	23(12-78) <0.03; >0.05	8(0-59) <0.001	ND	ND
p value 8	114(94-153) >0.05	7.6(4.2-13.5) >0.05	339(210-591) >0.05	30(7-73) >0.05	6(0-65) <0.001	ND	480(40-05,120) >0.05

Data are expressed as the median (range) of values from 20 patients; data from patient 15 were not included after week 2 (dropout). For rheumatoid factor (RF), only those patients with week 0 titers > 1/160 in the particle agglutination assay were included (No. = 14). P values show significance by Mann-Whitney test compared with week 0 values; adjusted for multiple statistical comparisons; ND = not done. Normal ranges: hemoglobin (Hgb) 120-160 g/liter (F), 135-175 g/liter (M); white blood cell count (WBC) 4-11x10^9/liter; platelet count 150-400 x 10^9/liter; erythrocyte sedimentation rate (ESR) < 15 mm/hour (F), <10 mm/hour (M); C-reactive protein (CRP) < 10 mg/liter; serum amyloid A (SAA) < 10 mg/ml.

Table 16

260793	270793	280793	290793	020893	200893	270893
ESR-77	ESR-47	BSR-58	ESR-77	ESR-77	ESR-46	ESR-38

All DMARDs were discontinued at least 1 month prior to trial entry. Patients were allowed to continue on a non-steroidal anti-inflammatory drug and/or prednisolone (< 12.5 mg/day) during the trial. The dosage of these agents was kept stable for 1 month prior to trial entry and during the course of the trial, and no parenteral corticosteroids were allowed during these periods. Simple analgesics were allowed ad libitum. Patients with other serious medical conditions were excluded. Specific exclusions included serum creatinine > 150 umol/liter (normal range 60-120 umol/liter), hemoglobin (Hgb) < 90 gm/liter (normal range 120-160 gm/liter [females]; 135-175 gm/liter [males]), white blood cell count (WBC) < $4x10^9$/liter (normal range 4-$11x10^9$/liter), platelet count < $100x10^9$/liter (normal range 150-$400x10^9$/liter), and abnormal liver function tests or active pathology on chest X-Ray.

All patients gave their informed consent for the trial, and approval was granted by the local ethics committee.

Treatment

The cA2 antibody was stored at 4°C in 20 ml vials containing 5 mg of cA2 per milliliter of 0.01 M phosphate buffered saline in 0.15M sodium chloride at a pH of 7.2 and was filtered through a 0.2 um sterile filter before use. The appropriate amount of cA2 was then diluted to a total volume of 300 ml in sterile saline and administered intravenously via a 0.2 um in-line filter over a 2 hour period.

Patients were admitted to hospital for 8-24 hours for each treatment, and were mobile except during infusions. The trial was of an open, uncontrolled design, with a comparison of two treatment schedules. Patients 1 to 5 and 11 to 20 received a total of 2 infusions, each of 10 mg/kg cA2, at entry to the study (week 0) and 14 days later (week 2). Patients 6 to 10 received 4 infusions of 5mg/kg activity included complete blood counts, C-reactive protein (CRP; by rate nephelometry) and the erythrocyte sedimentation rate (ESR; Westergren). Follow-up assessments were made at

monthly intervals after the conclusion of the formal trial period, in order to assess the duration of response.

Analysis of improvement in individual patients was made using two separate indices. Firstly, an index of disease activity (IDA) was calculated for each time point according to the method of Mallya and Mace (Mallya et al., *Rheumatol. Rehab.* 20:14-17 (1981), with input variable of morning stiffness, pain score, Ritchie Index, grip strength, ESR and Hgb. The second index calculated was that of Paulus (Paulus et al., *Arthritis Rheum.* 33:477-484 (1990) which uses input variables of morning stiffness, ESR, joint pain/tenderness, joint swelling, patient's and physician's global assessment of disease severity. In order to calculate the presence or otherwise of a response according to this index, two approximations were made to accommodate our data. The 28 swollen joint count used by us (nongraded; validated in Fuchs et al., *Arthritis Rheum.* 32:531-537 (1989)) was used in place of the more extensive graded count used by Paulus, and the patient's and physician's global assessments of response recorded by us were approximated to the global assessments of disease activity used by Paulus *infra*. In addition to determining response according to these published indices, we selected 6 disease activity assessments of interest (morning stiffness, pain score, Ritchie index, swollen joint count, ESR and CRP) and calculated their mean percentage improvement. We have used figures 25 and 26 to give an indication of the degree of improvement seen in responding patients.

Immunological Investigations - Rheumatoid factors were measured using the rheumatoid arthritis particle agglutination assay (RAPA, FujiBerio Inc., Tokyo, Japan), in which titers of 1/160 or greater were considered significant. Rheumatoid factor isotypes were measured by ELISA (Cambridge Life Sciences, Ely, UK). The addition of cA2 at concentrations of up to 200 ug/ml to these assay cA2, at entry, and days 4, 8 and 12. The total dose received by the 2 patient groups was therefore the same at 20 mg/kg.

Assessment

Safety Monitoring - Vital signs were recorded every 15 to 30 minutes during infusions, and at intervals for up to 24 hours post infusion. Patients were questioned concerning possible adverse events before each infusion and at weeks 1, 2, 3, 4, 6, and 8 of the trial. A complete physical examination was performed at screening and week 8. In addition, patients were monitored by standard laboratory tests including complete blood count, C3 and C4 components of complement, IgG, IgM and IgA, serum electrolytes, creatinine, urea, alkaline phosphatase, aspartate transaminase and total bilirubin.. Sample times for these tests were between 0800 and 0900 hours (pre-infusion) and 1200-1400 hours (24 hours post completion of the infusion). Blood tests subsequent to day 1 were performed in the morning, usually between 0700 and 1200 hours. Urine analysis and culture were also performed at each assessment point.

Response Assessment - The patients were assessed for response to cA2 at weeks 1, 2, 3, 4, 6 and 8 of the trial. the assessments were all made between 0700 and 1300 hours by the same observer. The following clinical assessments were made: duration of morning stiffness (minutes), paid score (0 to 10 cm on a visual analog scale), Ritchie Articular Index (maximum 69; Ritchie et al., *Quart. J. Med.* 147:393-406 (1968)), number of swollen joints (28 joint count; validated in Fuchs et al., *Arthritis Rheum.* 32:531-537 (1989), grip strength (0 to 300 mm Hg, mean of 3 measurements per hand by sphygmomanometer cuff) and an assessment of function (the Stanford Health Assessment Questionnaire (HAG) modified for British patients; 34). In addition, the patients' global assessments of response were recorded on a 5-point scale (worse, no response, fair response, good response, excellent response). Routine laboratory indicators of disease systems did not alter assay results (data not shown). Antinuclear antibodies were detected by immunofluorescence on HEpo 2 cells (Biodiagnostics, Upton, Worcs. UK) and antibodies to

extractable nuclear antigens were measured by counter immunoelectrophoresis with poly-antigen extract (Biodiagnostics). Sera positive by immunofluorescence were also screened for antibodies to DNA by the Farr assay (Kodak Diagnostics, Amersham, UK). Anti-cardiolipin antibodies were measured by ELISA (Shield Diagnostics, Dundee, Scotland). Serum amyloid A (SAA) was measured by sandwich ELISA (Biosource International, Camarillo, CA, USA). Antiglobulin responses to the infused chimeric antibody were measured by an in-house ELISA, using cA2 as a capture reagent.

Cytokine Assays - Bioactive TNF was measured in sera using the WEHI 164 clone 13 cytotoxicity assay (Espevik et al., *J. Imm. Methods* 95:99-105 (1986). Total IL - 6 was measured in sera using a commercial immunoassay (Medgenix Diagnostics, SA, Belgium) and by a sandwich ELISA developed 'in house' using monoclonal antibodies provided by Dr. F. di Padova (Basel, Switzerland). Microtiter plates were coated with monoclonal antibody LNI 314-14 at a concentration of 3 ug/ml for 18 hours at 4°C and blocked with 3% bovine serum albumin in 0.1M phosphate buffered saline, pH 7.2. Undiluted sera or standards (recombinant hIL - 6, 0-8.1 ug/ml) were added to the wells in duplicate and incubated for 18 hours at 4°C. Bound IL-6 was detected by incubation with monoclonal antibody LNI 110-14 for 90 minutes at 37°C, followed by biotin - labeled goat anti-murine IgG2b for 90 minutes at 37°C (Southern Biotechnology, Birmingham, AL). The assay was developed using streptavidin - alkaline phosphatase (Southern Biotechnology) and p-nitrophenylphosphate as a substrate and the optical density read at 405 nm.

Statistics - Comparisons between week 0 and subsequent time points were made for each assessment using the Mann - Whitney test. For comparison of rheumatoid factor (RAPA) titers, the data were expressed as dilutions before applying the test.

This was an exploratory study, in which pre-judgements about the optimal times for assessment were not possible. Although it has not been common practice to adjust

for multiple statistical comparisons in such studies, a conservative statistical approach would require adjustment of p values to take into account analysis at several time points. The p values have therefore been presented in two forms: unadjusted, and after making allowance for analysis at multiple time points by use of the Bonferroni adjustment. Where p values remained < 0.001 after adjustment, a single value only is given. A p value of < 0.05 is considered significant.

Results

Safety of cA2 - the administration of cA2 was exceptionally well tolerated, with no headache, fever, hemodynamic disturbance, allergy or other acute manifestation. No serious adverse events were recorded during the 8-week trial. Two minor infective episodes were recorded, patient 15 presented at week 2 with clinical features of bronchitis and growth of normal commensals only on sputum culture. She had a history of smoking and of a similar illness 3 years previously. The illness responded promptly to treatment with amoxicillin, but her second cA2 infusion was withheld and the data for this patient are therefore not analyzed beyond week 2. Patient 18 showed significant bacteriuria on routine culture at week 6 ($>10^5$/ml; lactose fermenting coliform), but was asymptomatic. This condition also responded promptly to amoxicillin.

Routine analysis of blood samples showed no consistent adverse changes in hematological parameters, renal function, liver function, levels of C3 or C4 or immunoglobulins during the 8 weeks of the trial. Four minor, isolated and potentially adverse laboratory disturbances were recorded. Patient 2 experienced a transient rise in blood urea, from 5.7 mmol/liter to 9.2 mmol/liter (normal range 2.5 to 7 mmol/liter), with no change in serum creatinine. This change was associated with the temporary use of a diuretic, prescribed for a non-rheumatological disorder. The abnormality normalized within 1 week and was classified as 'probably not' related to cA2. Patient 6 experienced a

transient fall in the peripheral blood lymphocyte count, from 1.6 to 0.8×10^9/liter (normal range 1.0 - 4.8×10^9/liter). this abnormality normalized by the next sample point (2 weeks later), was not associated with any clinical manifestations and was classified as 'possible related' to cA2. Patients 10 and 18 developed elevated titers of anti-DNA antibodies at weeks 6 and 8 of the trial, with elevated anti-cardiolipin antibodies being detected in patient 10 only. Both patients had a pre-existing positive antinuclear antibody and patient 10 had a history of borderline lymphocytopenia and high serum IgM. There were no clinical features of systemic lupus erythematosus and the laboratory changes were judged 'possibly related' to cA2.

Efficacy of cA2

Disease Activity - The pattern of response for each of the clinical assessments of disease activity and the derived IDA are shown in Table 13. All clinical assessments showed improvement following treatment with cA2, with maximal responses from week 3. Morning stiffness fell from a median of 180 minutes at entry to 5 minutes at week 6 ($p<0.001$, adjusted), representing an improvement of 73%. Similarly, the Ritchie Index improved from 28 to 6 at week 6, ($p<0.001$, adjusted, 79% improvement) and the swollen joint count fell from 18 to 5, ($p<0.001$, adjusted, 72% improvement). The individual swollen joint counts for all time points are shown in Figure 25. Grip strength also improved; the median grip strength rose from 77 (left) and 92 (right) mm Hg at entry to 119 (left) and 153 (right) mmHg at week 6 ($p<0.04$, $p<0.05$, left and right respectively; $p>0.05$ after adjustment for multiple comparisons). The IDA showed a fall from a median of 3 at entry to 1.7 at week 6 ($p<0.001$, adjusted). Patients were asked to grade their responses to cA2 on a 5 point scale. No patient recorded a response of 'worse' or 'no change' at any point in the trial. 'FaIr', 'good' and 'excellent' responses were classed as improvements of 1, 2 and 3 grades respectively. At week 6, the study group showed a median of 2 grades of improvement (Table 13).

We also measured changes in the patients' functional capacity, using the HAQ modified for British patients (range 0-3). The median (range) HAQ score improved from 2(0.9-3) at entry to 1.1 (0-2.6) by week 6, ($p<0.001$;$p<0.002$ adjusted).

The changes in the laboratory tests which reflect disease activity are shown in Table 14. the most rapid and impressive changes were seen in serum CRP, which fell from a median of 39.5 mg/liter at entry to 8 mg/liter by week 6 of the trial ($p<0.001$, adjusted; normal range<10 mg/liter), representing an improvement of 80%. Of the 19 patients with elevated CRP at entry, 17 showed falls to the normal range at some point during the trial. The improvement in CRP was maintained in most patients for the assessment period (Table 14 and Figure 26); the exceptions with high values at 4 and 6 weeks tended to be those with the highest starting values (data not shown). The ESR also showed improvement, with a fall from 55 mm/hour at entry to 23 mm/hour at week 6 ($p<0.03$; $p>0.05$ adjusted; 58% improvement; normal range <10 mm/hour, <15 mm/hour, males and females respectively). SAA levels were elevated in all patients at trial entry, and fell from a median of 245 mg/ml to 58 mg/ml at week 1 ($p<0.003$, adjusted; 76% improvement; normal range < 10/mg/ml) and to 80 mg/ml at week 2 ($p<0.04$, adjusted). No significant changes were seen in Hgb, WBC or platelet count at week 6, although the latter did improve at weeks 2 and 3 compared with trial entry (Table 14).

The response data have also been analyzed for each individual patient. The majority of patients had their best overall responses at week 6, at which time 13 assessed their responses as 'good' while 6 assessed their responses as 'fair'. Eighteen of the 19 patients who completed the treatment schedule achieved an improvement in the index of Disease Activity (Mallya et al., *Rheumatol. Rehab.* 20:14-17 (1981) of 0.5 or greater at week 6, and 10 achieved an improvement of 1.0 or greater. All patients achieved a response at week 6 according to the index of Paulus (Paulus

et al., *Arthritis Rheum.* 33:477-484 (1990). Finally, all patients showed a mean improvement at week 6 in the 6 selected measures of disease activity (as presented above) of 30% or greater, with 18 of the 19 patients showing a mean improvement of 50% or greater.

Although the study was primarily designed to assess the short-term effects of cA2 treatment, follow-up clinical and laboratory data are available for those patients followed for sufficient time (number = 12). The duration of response in these patients, defined as the duration of a 30% (or greater) mean improvement in the 6 selected disease activity measures, was variable, ranging from 8 to 25 (median 14) weeks.

Comparison of the clinical and laboratory data for patients treated with 2 infusions of cA2 (each at 10 m/kg) compared with those treated with 4 infusions (each at 5 mg/kg) showed no significant differences in the rapidity or extent of response (data not shown).

Immunological Investigations and cytokines - Measurement of rheumatoid factor by RAPA showed 14 patients with significant tiers (> 1/160) at trial entry. Of these, 6 patients showed a fall of at least 2 titers on treatment with cA2, while the remaining patients showed a change of 1 titer or less. No patient showed a significant increase in RF titer during the trial. The median RF titer in the 11 patients fell from 1/2, 560 at entry to 1/480 by week 8 ($p>0.05$; Table 14). Specific RF isotypes were measured by ELISA, and showed falls in the 6 patients whose RAPA had declined significantly, as well as in some other patients. Median values for the three RF isotypes in the 14 patients seropositive at trial entry were 119, 102 and 62 IU/ml (IgM, IgG and IgA isotypes respectively) and at week 8 were 81, 64 and 46 IU/ml ($p>0.05$).

We tested sera from the first 9 patients for the presence of bioactive TNF, using the WEHI 164 clone 13 cytotoxicity assay (Espevik et al., *J. Imm. Methods* 95:99-105 (1986). In 8 patients, serum sets spanning the entire trial

period were tested, while for patient 9, one pre-trial, one intermediate and the last available sample only were tested. The levels of bioactive TNF were below the limit of sensitivity of the assay in the presence of human serum (1 pg/ml). Since production of CRP and SAA are thought to be regulated in large part by IL-6, we also measured serum levels of this cytokine, using 2 different assays which measure total IL-6. In the Medgenix assay, IL-6 was significantly elevated in 17 of the 20 patients at entry. In this group, levels fell from 60 (18-500) pg/ml to 40 (0-230) pg/ml at week 1 ($p>0.05$; normal range <10 pg/ml) and to 32 (0-210) pg/ml at week 2 ($p<0.005$, $p<0.01$, adjusted). These results were supported by measurement of serum IL-6 in the first 16 patients in a separate ELISA developed in-house. IL-6 was detectable in 11 of the 16, with median (range) levels falling from 210 (25-900) pg/ml at entry to 32 (0-1,700) pg/ml at week 1 ($p<0.02$, $p<0.04$, adjusted; normal range < 10 pg/ml) and to 44 (0-240) pg/ml at week 2 ($p<0.02$, $p<0.03$, adjusted).

We tested sera from the first 10 patients for the presence of anti-globulin responses to the infused chimeric antibody, but none were detected. In many patients however, cA2 was still detectable in serum samples taken at week 8 and this can have interfered with the ELISA.

Discussion

This is the first report describing the use of anti-TNFα antibodies in human autoimmune disease. Many cytokines are produced in rheumatoid synovium, but we chose to target specifically TNFα because of mounting evidence that it was a major molecular regulator in RA. The study results presented here support that view and allow three important conclusions to be drawn.

First, treatment with cA2 was safe and the infusion procedure was well tolerated. Although fever, headache, chills and hemodynamic disturbance have all been reported following treatment with anti CD4 or anti CDw52 in RA, such features were absent in our patients. Also notable was the

absence of any allergic event despite repeated treatment with the chimeric antibody, although the interval between initial and repeat infusions can have been too short to allow maximal expression of any anti-globulin response. The continuing presence of circulating cA2 at the conclusion of the trial amy have precluded detection of antiglobulin responses, but also implied that any such responses were likely to be of low titre and/or affinity. Although we recorded 2 infective episodes amongst the study group, these were minor and the clinical courses were unremarkable. TNFα has been implicated in the control of listeria and other infections in mice (Havell et al., *J. Immunol.* 143:2894-2899 (1989), but our limited experience does not suggest an increased risk of infections after TNFα blockade in man.

The second conclusion concerns the clinical efficacy of cA2. The patients we treated had long-standing, erosive, and for the most part seropositive disease, and had each failed therapy with several standard DMARDs. Despite this, the major clinical assessments of disease activity and outcome (morning stiffness, paid score, Ritchie index, swollen joint count and HAQ score) showed statistically significant improvement, even after adjustment for multiple comparisons. All patients graded their response as at least 'fair', with the majority grading it as 'good'. In addition, all achieved a response according to the criteria of Paulus and showed a mean improvement of at least 30% in 6 selected disease activity measures.

The improvements in clinical assessments following treatment with cA2 appear to be at least as good as those reported following treatment of similar patients with anti-leukocyte antibodies. The two therapeutic approaches can already be distinguished, however, by their effects on the acute phase response, since in several studies of anti-leukocyte antibodies, no consistent improvements in CRP or ESR were seen. In contrast, treatment with cA2 resulted in significant falls in serum CRP and SAA, with normalization of values in many patients. The changes were rapid and marked,

and in the case of CRP, sustained for the duration of the study (Table 14). The falls in ESR were less marked, achieving statistical significance only when unadjusted (Table 14).

These results are consistent with current concepts that implicate TNFα in the regulation of hepatic acute phase protein synthesis, either directly, or by control of other, secondary, cytokines such as IL-6 (Fong et al., *J. Exp. Med.* 170:1627-1633 (1989), Guerne et al., *J. Clin. Invest.* 83:585-592 (1989)). In order to investigate the mechanism of control of the acute phase response in our patients, we measured serum TNFα and IL-6 before and after cA2 treatment. Bioactive TNFα was not detectable in baseline or subsequent sera. We used 2 different assays for IL-6, in view of previous reports of variability between different immunoassays in the measurement of cytokines in biological fluids (Roux-Lombard et al., *Clin. Exp. Rheum.* 10:515-520 (1992), and both demonstrated significant falls in serum IL-6 by week 2. These findings support the other objective laboratory changes induced by cA2, and provide *in vivo* evidence that TNFα is a regulatory cytokine for IL-6 in this disease. Amongst the other laboratory tests performed, rheumatoid factors fell significantly in 6 patients.

Neutralization of TNFα can have a number of beneficial consequences, including a reduction in the local release of cytokines such as IL-6 and other inflammatory mediators and modulation of synovial endothelial/leukocyte interactions. cA2 can also bind directly to synovial inflammatory cells expressing membrane TNFα, with subsequent in situ cell lysis.

The results obtained in this small series have important implications, both scientifically and clinically. At the scientific level, the ability of the neutralizing antibody, cA2, to reduce acute phase protein synthesis, reduce the production of other cytokines such as IL-6, and significantly improve the clinical state demonstrates that it is possible to interfere with the cytokine network in a

useful manner without untoward effects. Due to the many functions and overlapping effects of cytokines such as IL-1 and TNFα, and the fact that cytokines induce the production of other cytokines and of themselves, there had been some pessimism as to whether targeting a single cytokine *in vivo* would have any beneficial effect (Kingsley et al., *Immunol. Today* 12:177-179 (1991), Trenthan, *Curr. Opin. Rheumatol.* 3:369-372 (1991)). This view is clearly refuted. On the clinical side, the results of short-term treatment with cA2 are significant and confirm that TNFα is useful as a new therapeutic target in RA.

EXAMPLE XXIII: TREATMENT WITH CHIMERIC ANTI-TNF IN A PATIENT WITH SEVER ULCERATIVE COLITIS.

The patient is a 41 year old woman with long term ulcerative colitis, which was diagnosed by endoscopy and histology. She has a pancolitis, but the main disease activity was left-sided. There were no extra-intestinal complications in the past. Maintenance therapy consisted of Asacol(TM). Only one sever flair-up occurred 4 years previously and was successfully treated with steroids.

At beginning month one, she was admitted elsewhere because of a very sever flair-up of the ulcerative colitis. Treatment consisted of high doses of steroids intravenously, antibiotics, asacol and Total Parental Nutrition. Her clinical condition worsened and a colectomy was considered.

At end of month one, she was admitted at the internal ward of the AMC. Her main complaints consisted of abdominal pains, frequent water stools with blood and mucopus and malaise.

Medication: ASACOL 2 dd 500 mg, orally
Di-Adresone-T 1 dd 100 mg, intravenously
Flagyl 3 dd 500 mg, intravenously
Fortum 3 dd 1 gram, intravenously
Total parental nutrition via central venous catheter

On physical examination the patient was moderately ill with a weight of 55 kg and a temperature of 36 °C.

Jugular venous pressure was not elevated. Blood pressure was 110/70 mm Hg with a pulse rate of 80 per minute. No lymphadenopathy was found. Oropharynx was normal. Central venous catheter was inserted *in situ* with no signs of inflammation at the place of insertion. Normal auscultation of the lungs and heart. The abdomen was slightly distended and tender. Bowel sounds where reduced. Liver and spleen where not enlarged. No signs of peritonitis. Rectal examination was normal.

All cultures of the stools where negative.

Plain x-ray of the abdomen; slightly dilated colon. No thumb-printing, no free air, no toxic megacolon.

Sigmoidoscopy; (video-taped) Very severe inflammation with deep ulcers. Dilated rectum and sigmoid. Because of danger of perforation the color, the endoscopy was limited to the racto-sigmoid. No biopsies where taken.

Conclusion at time of admission: Severe steroid resistant flair-up of ulcerative colitis.

Antibiotics where stopped, because no improvement was noticed and there was no temperature.

After informed consent of the patient, treatment was started with 10 mg/kg bodyweight (a 550 mg) of cA2 chimeric monoclonal anti-TNF (Centocor) given intravenously over 2 hours (according the protocol of cA2 used in severe Crohn's disease).

During the infusion there where no complaints. Vital signs where monitored and where all normal. Before and after infusion blood samples where drawn. Two days after infusion she had less abdominal pain, the stool frequency decreased and no blood was seen in the stools any more. However she developed high temperature (40 °C). Bloodcultures where positive for *Staphylococcus epidermidis*. Infection of the central venous catheter was suspected. The catheter was removed and the same Staphylococcus was cultured from the tip of the central venous catheter. During this period she was treated with antibiotics for three days. After this her temperature dropped and she recovered

substantially. Steroids where tapered off to 40 mg of prednisone daily.

After 14 days sigmoidoscopy was repeated and showed a remarkable improvement of the mucosa with signs of re-epithelization. There where no signs of bleeding, less mucopus and even some normal vascular structures where seen.

At four months she was discharged.

At the outpatient clinic further monitoring was done weekly. Patient is still improving. Stool frequency is two times per day without blood or mucopus. Her laboratory improved, but there is still anaemia, probably due to iron deficiency. A colonoscopy is planned in the nearby future.

Our conclusion is that this patient had a very severe flair-up of her ulcerative colitis. She was refractory to treatment and a total colectomy was seriously considered. After infusion of cA2 the clinical course improved dramatically in spite of the fact that there was a complication of a sepsis which was caused by the central venous catheter.

Example XXIV
p55 Fusion protein structure

The extracellular domains of the p55 and p75 receptors were expressed as Ig fusion proteins from DNA constructs designed to closely mimic the structure of naturally occurring, rearranged Ig genes. Thus, the fused genes included the promoter and leader peptide coding sequence of a highly expressed chimeric mouse-human antibody (cM-T412, Looney et all, *Hum. Antibody Hybridomas* 1992, 3, 191-200) on the 5' side of the TNF receptor insert, and codons for eight amino acids of human J sequence and a genomic fragment encoding all three constant domains of human IgG1 on the 3' side of the receptor insert position (Figures 28 and 29).

Minor changes were introduced at the N-terminal ends of the heavy chain fusion proteins so that the first two amino acids would be identical or similar to the first two amino acids (Gln-Ile) encoded by the cM-T412 antibody gene

(from which the leader peptide originated). This was done to increase the likelihood that any interactions between the N-terminal end of the mature protein and the leader peptide would still result in efficient transport into the lumen of the endoplasmic reticulum. Boyd et al., *Cell* 1990, 62, 1031-1033. Therefore, the Asp^1 and Ser^2 residues of naturally-occurring p55 were replaced with a Gln residue, and the Leu^1 residue of p75 was preceded by a Gln residue in all p75 constructs. No amino acid changes were introduced at the N-terminal end of the p55 light chain fusion.

Expression vectors

PCR methodology was used to engineer cloned genes. Oligonucleotides were purchased from National Biosciences (Plymouth, MN). PCR amplification kits were from Perkin-Elmer (CA) and DNA sequencing kits from U.S. Biochemical Corporation (Cleveland, OH). Alkaline phosphatase-conjugated goat anti-human IgG was purchased from Jackson ImmunoResearch (West Grove, PA). ^{125}I-labeled human TNF was obtained from Du Pont Company, NEN (Boston, MA) and unlabeled recombinant human TNF from R&D Systems (Minneapolis, MN). Protein A-Sepharose beads was purchased from PHARMACIA (Piscataway, NJ).

PCR methodology was used to engineer two cloned genes encoding the heavy chain or light chain of an efficiently expressed murine antibody, cM-T412 (see Looney et al.), for the purpose of directing the expression of foreign genes in a mammalian cell system. The approaches were to effectively delete the coding region of the antibody variable region and to place a unique restriction site in its place (StuI for the heavy chain vector and EcoRV for the light chain vector).

The resulting vector contained 2.5 kb of 5' flanking genomic DNA, the promoter, the leader peptide coding sequence (including the leader intron), a StuI cloning site to introduce inserts, coding sequence for eight amino acids of human J sequence Gly Thr Leu Val Thr Val Ser Ser (SEQ ID

NO:6) followed by genomic sequences for the human IgG1 constant region. An analogous vector was made from the cM-T412 light chain gene except that an EcoRV cloning site was introduced at the carboxyl terminal end of the light chain leader peptide and a different human J sequence was encoded by the vector Gly Thr Lys Leu Glu Ile Lys (SEQ ID NO:7). Both vectors are based on plasmid pSV2-gpt and subsequent vector derivatives that contain genomic sequences for either the heavy chain or light chain constant regions. See Mulligan et al., *Science* 209:1422-1427 (1980). The *E. coli gpt* gene allows selection of transfected cells with mycophenolic acid.

Heavy chain vector

A previously cloned EcoRI fragment containing the cM-T412 heavy chain gene (Goeddel et al., *Cold Spring Harbor Symp. Quant. Biol.* 1986, 51, 597-609) was subcloned into pUC19. This recombinant plasmid was used as a template for two PCR reactions. In one reaction, an oligo corresponding to the "reverse" primer of the pUC plasmids and the 3' oligo 5'-CCTGGATACCTGTGAAAAGA-3' (SEQ ID NO:8) (bold marks half of a StuI site; oligo was phosphorylated prior to the PCR reaction) were used to amplify a fragment containing 3kb of 5' flanking DNA, the promoter, transcription start site and leader peptide coding sequence (including the leader intron). In the second reaction, the 5' oligo 5'-CCTGGTACCTTAGTCACCGTCTCCTCA-3' (SEQ ID NO:9) (bold marks half of a StuI site; oligo phosphorylated prior to the PCR reaction) and an oligo corresponding to the "forward" primer of pUC plasmids amplified a fragment encoding eight amino acids of human J sequence Gly Thr Leu Val Thr Val Ser Ser (SEQ ID NO:6) and a splice donor to allow splicing to the human constant region coding sequence provided in another vector. The two PCR fragments were digested with EcoRI and then simultaneously ligated into EcoRI-digested pUC19 to make pHC684 (Figure 28).

Because the StuI site formed at the junction of the two PCR fragments was followed by a 'GG' dinucleotide

sequence, a *dcm* methylation site was formed preventing StuI from digesting that site when the DNA was grown in HB101 strain of *E coli*. Therefore, the plasmid DNA was introduced into *dcm*- JM110 *E. coli* cells and reisolated. StuI was then able to cut at the junction but a second StuI site in the 5' flanking DNA was a apparent (DNA sequencing showed that StuI site to also he followed by a GG dinucleotide and therefore also methylated). To make the StuI cloning site at the junction be unique, a 790 bp XbaI fragment that included only one of the two StuI sites was subcloned into pUC19 to make the vector pHC707 (Figure 28A) which was then grown in JM110 cells. The StuI cloning site formed at the junction of the two PCR fragments second and third nucleotides (i.e., 'CA') of the last codon (Ala) of the signal sequence in order to maintain the appropriate translation reading frame (Figure 28).

A PCR fragment encoding a protein of interest can then be ligated into the unique StuI site of pHC707. The insert can include a translation stop codon that would result in expression of a "non-fusion" protein. Alternatively, a fusion protein could be expressed by the absence of a translation stop codon, thus allowing translation to proceed through additional coding sequences positioned downstream of the StuI cloning site. pHC707 at a unique XbaI site upstream of the IgG1 coding sequences (Figure 29). Coding sequences in the StuI site of pHC707 would not be fused directly to the IgG1 coding sequences in pHC730 but would be separated by an intron sequence that partially originates from pHC707 and partially from pHC730. These intron sequences would be deleted in the cell following transcription resulting in an RNA molecule that is translated into a chimeric protein with the protein of interest fused directly to the IgG1 constant domains.

The plasmid pHC730 was a modified form of an IgG1 expression, pSV2gpt-hCyl vector described previously (Goeddel et al., *Cold Spring Harbor Symp. Quant. Biol.* 1986, 51, 597-609) (Figure 28B). The modifications were (1) removal of the

unique Sal1 and Xbal sites upstream of the constant region coding sequence, (2) insertion of a Sal1 linker into the unique BamHI site to allow use of Sal1 to linearize the plasmid prior to transfections, and (3) ligation into the unique EcoRI site the cloned cM-T412 EcoRI fragment but with the Xbal fragment flanking the V gene deleted (Figure 30). The resulting expression vector had a unique Xbal site for inserting the Xbal fragments from pHC707.

Light chain vector

A previously cloned HindIII fragment containing the cM-T412 light chain gene (Goeddel et al., *Cold Spring Harbor Symp. Quant. Biol.* 1986, 51, 597-609) was subcloned into pUC19 and the resulting plasmid used as template for PCR reactions. In one PCR reaction the "reverse" pUC primer and the 3' oligo 5'-AATAGATATCTCCTTCAACACCTGCAA-3' (SEQ ID NO:10) (EcoRV site is in bold) were used to amplify a 2.8 kb fragment containing 5' flanking DNA, the promoter, transcription start site and leader peptide coding sequence (including the leader intron) of the cloned light chain gene. This fragment was then digested with HindIII and EcoRV. In a second PCR reaction, the 5' oligo 5'-ATCGGGACAAAGTTGGAAATA-3' (SEQ ID NO:11) (bold marks half of an EcoRV site) and the "forward" pUC primer ware used to amplify a fragment encoding seven amino acids of human J sequence (Gly Thr Lys Leu Glu Ile Lys) and an intron splice donor sequence. This fragment was digested with HindIII and ligated along with the other PCR fragment into pUC cut with HindIII. The resulting plasmid, pLC671 (Figure 30), has a unique EcoRV cloning site at the junction of the two PCR fragments with the EcoRV site positioned such that the first three nucleotides of the EcoRV site encoded the first amino acid of the mature protein (Asp).

The pLC671 HindIII insert was designed to be positioned upstream of coding sequences for the human kappa light chain constant region present in a previously described expression vector, pSV2gpt-hCk (Figure 31). However, pSV2gpt-hCk contained an EcoRV site it its *gpt* gene. Because

it was desired that the EcoRV site in the pLC671 HindIII fragment be a unique cloning site after transferring the fragment into pSV2gpt-hCk, the EcoRV site in pSV2gpt-hCk was first destroyed by PCR mutagenesis. Advantage was taken of the uniqueness of this EcoRV site in pSV2gpt-hCk and a Kpn1 site 260 bp upstream of the EcoRV site. Therefore, the 260 bp Kpn1-EcoRV fragment was removed from pSV2gpt-hCk and replaced with a PCR fragment that has identical DNA sequence to the 260 bp fragment except for a single nucleotide change that destroys the EcoRV site. The nucleotide change that was chosen was a T to a C in the third position of the EcoRV recognition sequence (i.e., GATATC changed to GACATC). Because the translation reading frame is such that GAT is a codon and because both GAT and GAG codons encode an Asp residue, the nucleotide change does not change the amino acid ended at that position. Specifically, pSV2gpt-hCk was used as template in a PCR reaction using the 5' oligo 5'-GGCGGTCTGGTACCGG-3' (SEQ ID NO:12) (Kpn1 site is in bold) and the 3' oligo 5'-GTCAACAACATAGTCATCA-3' (SEQ ID NO:13) (bold marks the complement of the ASP codon). The 260 bp PCR fragment was treated with the Klenow fragment of DNA polymerase to fill-in the DNA ends completely and then digested with Kpn1. The fragment was ligated into pSV2gpt-hCk that had its Kpn1-EcoRV fragment removed to make pLC327 (Figure 31).

The HindIII fragment of pLC671 was cloned into the unique HindIII site of pLC327 to make the light chain expression vector, pLC690 (Figure 31). This plasmid can be introduced into cells without further modifications to encode a truncated human kappa light chain, JCk, that contains the first two amino acids of the cM-T412 light chain gene, seven amino acids of human J sequences, and the light chain constant region. Alternatively, coding sequence of interest can be introduced into the unique EcoRV site of pLC690 to make a light chain fusion protein.

TNF receptor DNA constructs

For the p55 heavy chain fusion, amino acids 3-159

of the p55 extracellular domain were encoded in a PCR fragment generated using the 5' oligo 5'-CACAGGTGTGTCCCCAAGGAAAA-3' (SEQ ID NO:14) (bold marks the Val^3 codon) and the 3' oligo 5'-AATCTGGGGTAGGCACAA-3' (SEQ ID NO:15) (bold marks the complement of the Ile^{159} codon). For the p55 light chain fusion, amino acids 2-159 were encoded in a PCR fragment made Using the 5' oligo 5'-AGTGTGTGTCCCCAAGG-3' (SEQ ID NO:16) (bold marks the Ser^2 codon) and the same 3' oligo shown above. The light chain vector contained the codon for Asp^1 of p55. The DNA template for these PCR reactions was a previously reported human p55 cDNA clone. Gray et al., *Proc. Natl. Acad. Sci. USA* 1990, 87, 7380-7384.

A truncated light chain that lacked a variable region was expressed by transfecting cells with the light chain vector with no insert in the EcoRV cloning site. The resulting protein, termed JC_K, consisted of the first two amino acids of the cM-T412 light chain gene, seven amino acids of human J sequence (Gly Thr Lys Leu Glu Ile Lys) (SEQ ID NO:7), and the human light chain constant region.

A non-fusion form of p55 (p55-nf) was expressed in CHO-K1 cells using the CMV-major immediate early promoter after introducing a translation stop codon immediately after Ile^{159}. Secreted p55 was purified by affinity chromatography on a TNFα column.

Transfections and ELISA assays

All plasmids were linearized with a restriction enzyme prior to introducing them into cells. Cells of the myeloma cell line X63-Ag8.653 were transfected with 12 μg of DNA by electroporation. Cell supernatants were assayed for IgG domains. Briefly, supernatants were incubated in plates coated with anti-human IgG Fc and then bound protein detected using alkaline phosphatase-conjugated anti-human and light chains.

Purification of fusion proteins

Cell supernatants were clarified by centrifugation followed by passage through a 0.45 micron filter.

Supernatants were adjusted to 20 mM Tris-HCl, pH 8.3, 150 mM NaCl, and 1 mM EDTA (1 X protein A buffer) and passed over a column of protein A-Sepharose beads. The column was washed in 1X protein A buffer followed by 100 mM Na Citrate, pH 5.0 to elute bound bovine IgG originating from the cell media. Bound fusion protein was then eluted in 100 mM Na Citrate, pH 3.5, neutralized with 0.2 volumes 1 M Tris, and dialyzed against PBS.

TNF cytotoxicity assays

TNF-sensitive WEHI-164 cells (Espevik et al., *J. Immunol. Methods* 1986, 95, 99-105) were plated in 1 μg/ml actinomycin D at 50,000 cells per well in 96-well microtiter plates for 3-4 hours. Cells were exposed to 40 pM TNFα or TNFβ and varying concentrations of fusion protein. The mixture was incubated overnight at 37°C. Cell viability was determined by adding 3-[4,5-dimethyl-thiazol-2-yl]-2, 5-diphenyltetrazolium bromide dye (MTT) to a final concentration of 0.5 mg/ml, incubating for 4 hours at 37°C, lysing the cells in 0.1 N HCl, 0.1% SDS and measuring the optical density at 550 nm wavelength.

Saturation binding analyses

Fusion proteins were captured while at a concentration of 10 ng/ml in 96-well microtiter plates coated with goat anti-human Fc antibodies. Varying concentrations of ^{125}I-TNF (34.8 μCi/μg) were added in PBS/1% BSA and allowed to bind for two hours at room temperature. Plates were washed and bound cpm determined. Non-specific binding was determined using an irrelevant antibody.

Several different versions of the p55 fusion proteins were expressed. Unlike what was reported for CD4 (Capon et al., *Nature* 1989, 337, 525-531) and IL-2 (Landolfi, *J. Biol. Chem.* 1991, 146, 915-919) fusion proteins that also included the C_H1 domain of the heavy chain, inclusion of a light chain proved to be necessary to get secretion of the Ig heavy chain fusion proteins from the murine myeloma cells. The light chain variable region was deleted to enable the TNF

R domain on the heavy chain to bind TNF without stearic hindrance from the light chain.

The "double fusion" (df) protein, p55-df2, has p55 fused to both the heavy chain and light chain and is therefore tetravalent with regard to p55. p55-sf3 has the p55 receptor (and the same eight amino acids of human J sequence present in p55-sf2 and p55-df2) linked to the hinge region, i.e., the C_H1 domain of the constant region is deleted.

After one or two rounds of subcloning, spent cell supernatant from the various cell lines were yielding 20 μg/ml (for p55-sf2) of fusion protein. The proteins were purified from the spent supernatant by protein A column chromatography and analyzed by SDS-PAGE with or without a reducing agent (Figure 32). Each fusion protein was clearly dimeric in that their M_r estimates from their migration through a non-reducing gel was approximately double the estimated M_r from a reducing gel. However, two bands were seen for p55-sf2 (Figure 32, lane 1) and p55-df2. Two lines of evidence indicated that, in each case, the lower bands did not include a light chain while the upper bands did include a light chain. First, when p55-sf2 containing both bands were passed over an anti-kappa column, the upper band bound to the column (lane 3) while the lower band passed through the column. Second, Western blots have shown that only the upper bands were reactive with anti-kappa antibodies.

It is believed that the versions of these fusion proteins that do not have a light chain (k) were not secreted to a significant degree but rather were primarily released from dead cells because 1) supernatants from cells transfected with the p55 heavy chain fusion gene and no light chain gene did not have detectable fusion protein until after there was significant cell death, and 2) the ratio of the k- to k+ versions of p55-sf2 increased as cell cultures went from 95% viability to 10% viability.

WEHI cytotoxicity assays

The ability of the various fusion proteins to bind and neutralize human TNFα or TNFβ was tested In a TNF-mediated cell killing assay. Overnight incubation of the murine fibrosarcoma cell line, WEHI 164 (Espevik et al., *J. Immunol. Methods* 1986, 95, 99-105), with 20 pM (1 ng/ml) TNFα results in essentially complete death of the culture. When the fusion proteins were pre-incubated with TNFα (Figure 33A) or TNFβ (Figure 33B and Table 1 above) and the mixture added to cells, each fusion protein demonstrated dose-dependent protection of the cells from TNF cytotoxicity. Comparison of the viability of control cells not exposed to TNF to cells incubated in both TNF and fusion protein showed that the protection was essentially complete at higher concentrations of fusion protein.

Tetravalent p55-df2 showed the greatest affinity for TNFα requiring a concentration of only 55 pM to confer 50% inhibition of 39 pM (2 ng/ml) TNFα (Figure 33A and Table 1). Bivalent p55-sf2 and p75P-sf2 were nearly as efficient, requiring concentrations of 70 pM to half-inhibit TNFα. Approximately two times as much p75-sf2 was required to confer 50% inhibition compared to p55-sf2 at the TNF concentration that was used. The monomeric, non-fusion form of p55 was much less efficient at inhibiting TNFα requiring a 900-fold molar excess over TNFα to inhibit cytotoxicity by 50%. This much-reduced inhibition was also observed with a monomeric, Fab-like p55 fusion protein that was required at a 2000-fold molar excess over TNFα to get 50% inhibition. The order of decreasing inhibitory activity was therefore p55-df2 > p55-sf2 = p75P-sf2 > p75-sf2 >>> monomeric p55.

Example XXV p75

To make a p75 heavy chain fusion (p75-sf2), amino acids 1-235 (Smith et al., *Science* 1990, 248, 1019-1023 and Kohno et al., *Proc. Natl. Acad. Sci.* 1990, 87, 8331-8335) were encoded in a fragment prepared using the 5' oligo 5'-CACAGCTGCCCGCCCAGGTGGCAT-3' (SEQ ID NO:17) (bold marks the Leu^1 codon) and the 3' oligo 5'-GTCGCCAGTGCTCCCTT-3' (SEQ ID

NO:18) (bold marks the complement of the Asp^{235} codon). Two other p75 heavy chain fusions (p75P-sf2 and p75P-sf3) were made using the same 5' oligo with the 3' oligo 5'-ATCGGACGTGGACGTGCAGA-3' (SEQ ID NO:19). The resulting PCR fragment encoded amino acids 1-182. The PCR fragments were blunt-end ligated into the StuI or EcoRV site of the appropriate vector and checked for the absence of errors by sequencing the inserts completely.

Several different versions of the p75 fusion proteins were also expressed. p75-sf2 has the complete extracellular domain of p75 fused to the heavy chain while p75P-sf2 lacks the C-terminal 53 amino acids of the p75 extracellular domain. p75P-sf3 is the same as p75P-sf2 except that it lacks the C_H1 domain. The region deleted in p75P-sf2 and -sf3 contains sites of 0-linked glycosylation and a proline-rich region, neither of which is present in the extracellular domain of p55. Seckinger et al., *Proc. Nat. Acad. Sci. USA* 1990, 87, 5188-5192.

Similar to p55-sf2, as presented in Figure 32, two bands were seen for p75-sf2 (Figure 32A, lane 7) and p75P-sf2 (Figure 32B, lane 8).

Surprisingly, the order of decreasing inhibitory activity was different for TNFβ, as presented in Figure 34. p75P-sf2 was most efficient at inhibition requiring a concentration of 31 pM to half-inhibit human TNFβ at 2 pM. Compared to p75P-sf2, three times as much p75-sf2 and three times as much p55-sf2 were necessary to obtain the same degree of inhibition. The order of decreasing inhibitory activity was therefore p75P-sf2 > p75-sf2 ≈ p55-sf2.

Affinity measurements

A comparison was made of the binding affinity of various fusion proteins and TNFα by saturation binding (Figure 35A) and Scatchard analysis (Figure 35B). A microtiter plate was coated with excess goat anti-Fc polyclonal antibody and incubated with 10 ng/ml of fusion protein in TBST buffer (10 mM Tris-HCl, pH 7.8, 150 NaCl,

0.05% Tween-20) for 1 hour. Varying amounts of ^{125}I labeled TNFα (specific activity - 34.8 μCi/μg) was then incubated with the captured fusion protein in PBS (10 mM Na Phosphate, pH 7.0, 150 mM NaCl) with 1% bovine serum albumin for 2 hours. Unbound TNFα was washed away with four washes in PBS and the cpm bound was quantitated using a y-counter. All samples were analyzed in triplicate. The slope of the lines in (B) represent the affinity constant, K_a. The dissociation constant (K_d) values (see Table 1) were derived using the equation $K_d = 1/K$.

Example XXVI *In vivo results*

C3H mice were challenged with 5 μg of human TNFα after treatment with an immunoreceptor molecule of the invention. The effect of the treatment was compared with two control treatments. The first control, cA2, is a chimeric mouse/human IgG_1 monoclonal antibody that binds human TNF, and thus is a positive control. The second control, c17-1A, is a chimeric mouse/human IgG_1 irrelevant monoclonal antibody and is thus a negative control. The results of the treatments were as presented in the following Table 17.

TABLE 17

Treatment	Dead Fraction	% Dead
1μg cA2	5/14	36%
10μg cA2	1/15	7%
50μg c17-1A	13/15	87%
1μg p55-sf2	8/15	53%
10μg p55-sf2	0/15	0%
50μg p55-sf2	0/15	0%

Mice were injected with 25 μg of p55 fusion protein or a control antibody and 1 hour later were challenged with 1 μg lipopolysaccharide (type J5). Mice were checked 24 hours later. The results are presented in the following Table 18.

TABLE 18

Treatment	Dead Fraction	% Dead
Control Antibody	11/11	100%
p55-sf2	0/13	0%

All references cited herein, including journal articles or abstracts, published or corresponding U.S. or foreign patent applications, issued U.S. or foreign patents, or any other references, are entirely incorporated by reference herein, including all data, tables, figures, and text presented in the cited references. Additionally, the entire contents of the references cited within the references cited herein are also entirely incorporated by reference.

Reference to known method steps, conventional methods steps, known methods or conventional methods is not in any way an admission that any aspect, description or embodiment of the present invention is disclosed, taught or suggested in the relevant art.

The foregoing description of the specific embodiments will so fully reveal the general nature of the invention that others can, by applying knowledge within the skill of the art (including the contents of the references cited herein), readily modify and/or adapt for various applications such specific embodiments, without undue experimentation, without departing from the general concept of the present invention. Therefore, such adaptations and modifications are intended to be within the meaning and range of equivalents of the disclosed embodiments, based on the teaching and guidance presented herein. It is to be understood that the phraseology or terminology herein is for the purpose of description and not of limitation, such that the terminology or phraseology of the present specification is to be interpreted by the skilled artisan in light of the teachings and guidance presented herein, in combination with the knowledge of one of ordinary skill in the art.